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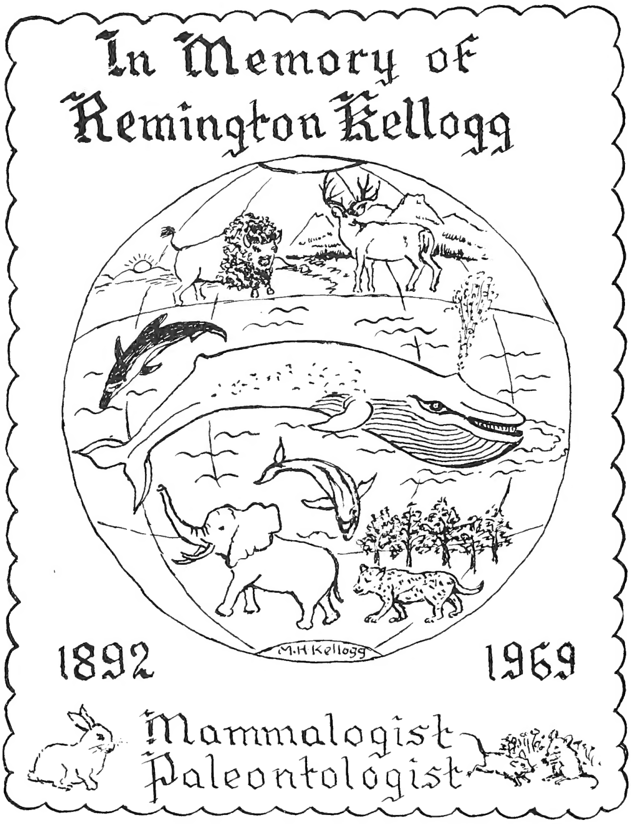
M.H Kellogg

CONTRIBUTIONS TO PALAEONTOLOGY

MARINE MAMMALS

By Earl L. Packard, Remington Kellogg, and Ernst Huber

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LIST OF PAPERS

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I

A NEW CETOTHERE FROM THE MIOCENE ASTORIA FORMATION OF NEWPORT, OREGON

By Earl L. Packard and Remington Kellogg

With three plates and twenty-four text-figures

[Issued January 10, 1934]

CONTENTS

A NEW CETOTHERE FROM THE MIOCENE ASTORIA FORMATION OF NEWPORT, OREGON

INTRODUCTION

Since the time of the early discoveries of Thomas Condon (1906), cetaceans, pinnipeds and the peculiar marine *Desmostylus* have been known to occur in the Miocene deposits in the vicinity of Newport, Lincoln County, Oregon. Various authors including Merriam (1911), McCornack (1914), Hay (1915), Hannibal (1922), Packard (1921) and Kellogg (1922) have reported the discovery of, or have described or referred to fossil mammalian material from that coastal region. The note by Packard records the finding of a well-preserved skeleton of a cetothere, the description of which is the principal purpose of this paper.

The cetothere here described was discovered by the senior author in 1920 near the high-tide mark on the ocean beach about 1000 feet northwest of the Old Tower (C. G. 128) at Newport. The skeleton was lying in a nearly horizontal position, with the inferior margin of a part of each mandible and the palatal region of the skull partially exposed. The exact stratigraphic position of this skeleton within the Astoria formation has not been determined, but it is probably in the lower half of the section as exposed locally. The matrix in which it was imbedded consists of a fissile sandy shale, which rapidly crumbles when exposed to the air.

An imperfectly preserved cetothere cranium was found a few years later by Dr. Eugene Callaghan, while a student at the University of Oregon. A similar specimen has been discovered recently by Mr. J. C. Snyder of Otter Rock, Oregon. In addition to these specimens, the senior author has examined more than a hundred vertebræ and fragments of mandibles that have been picked up by visitors to these Oregon beaches.

The cost of excavation and part of the expenses of preparation of the specimen found by the senior author was covered by a grant from the University of Oregon Research Committee. The senior author was assisted in the excavation of this specimen by his student, Miss Rachel Husband, who also did much of the work of preparation. Acknowledgments are likewise due to Dr. Elton Edge, who made a preliminary examination of the specimen, and to Messrs. Sam Itzikowitz and Ernest McKittrick and Miss Margaret Elaine Williams for assistance in the preparation and study of the specimen. Mr. J. C. Snyder has generously loaned his specimen for study. To Dr. Hubert H. Schenck and Robert M. Kleinpell the writers are indebted

for information in regard to the invertebrate fauna of the Astoria formation. The drawings are the work of Sydney Prentice and the preparation of this report has been made possible by a grant from the Carnegie Institution of Washington.

A brief résumé of the geology of this region is given in so far as it bears on the age of this assemblage of fossil marine mammals.

GENERAL GEOLOGY OF THE NEWPORT REGION

Various authors have incidentally referred to the geology or palæontology of the Newport region. Several papers relating to the geology of this region or to its fossil invertebrate fauna contain reviews of the work accomplished by previous investigators. Therefore only a few of the more important citations need be mentioned. Among these are papers by Condon (1880), Diller (1896), Dall (1909), Washburne (1914), Clark (1921, 1925, 1926), Arnold and Hannibal (1913), Smith and Packard (1919), Harrison and Eaton (1920), Hertlein (1925), Howe (1926), Schenck (1928), Smith (1926), and more recently Etherington (1931). The latest report discussing the geology of this coastal region is by Schenck (1928), which has been drawn upon freely in writing the present paper.

Schenck (1928, p. 23) has summarized the geology of the Newport region and has published a sketch map and geologic sections of Yaquina Bay and Alsea Bay. The Yaquina Bay section extends from a point south of Toledo westward to the ocean shore where it terminates in a stack locally known as "Jump-off-Joe," situated just north of Newport. The section represents a thick series of Oligocene and Miocene shales and sandstones. It forms a westward dipping series that strikes nearly parallel with the shoreline. Harrison and Eaton (1920, p. 6), incorporating a column by Smith, divided the Oligocene into three divisions. Schenck recognized these divisions but substituted the "Nye formation" for the "Acila shales." The lowermost Oligocene, the Toledo, is not known to contain marine mammals and since it does not enter into the beach sections, it is not described in this paper.

The second division, known as the Yaquina formation, is typically exposed along the north shore of Yaquina Bay near the town of Yaquina. It also occurs along both the north and south sides of Alsea Bay. At the type locality it consists of about 4000 feet of "coarse-grained buff-colored sandstones interbedded with carbonaceous beds" (Harrison & Eaton, p. 13) grading up into fine-grained micaceous blue-gray sandstones. In some places, especially at Yaquina town, these beds contain many fossil invertebrates, and may have yielded the centra of the marine mammal referred to on page 22.

These rocks rest conformably upon the Toledo Oligocene and are unconformably overlain by the Nye shales. The latter are missing in the Alsea section, for the Astoria Miocene is there in contact with fossiliferous Yaquina sandstones.

The Nye shales overlie the Yaquina sandstones and are exposed along the north shore of Yaquina Bay at least as far as the western end of Bay Boulevard along the waterfront at Newport. They outcrop at the base of the seacliff just north of the "arched rock" at the northern end of Nye Beach; also back of Jump-off-Joe and at several places along the seacliff or along the beach north to the "Devil's Punch Bowl" near Otter Rock, about nine miles north of Yaquina Bay. They occur as slightly embayed slump areas protected somewhat by the more resistant Miocene sandstones that form the bolder cliffs of the nearly straight shoreline. Schenck (1928, p. 28) states that the "Nye shale overlies the Yaquina sandstone, the contact paralleling the eastern end of Yaquina Bay. The difference in dip and strike between the shale and underlying sandstone shows that an unconformity separates them." In places, especially north of Spencer Creek, the upper contact of these shales lies at the beach level, usually being concealed beneath shifting sands and gravels. The Nye shales appear to be absent in the Alsea sections recorded by Schenck. They do not appear along the ocean front at Seal Rocks nor at any known locality farther south.

The contact between the Nye shales and the overlying Miocene is unknown south of Yaquina Bay. It is concealed beneath dune sands west of the settled portion of the town of Newport, but appears along the shore just north of the "Arch rock" at Nye Beach. North of that point the contact roughly parallels the shoreline so that the Nye shales may be expected in the cliffs or even on the wave-cut bench.

The character of the Nye shales is such that the true structure is frequently obscured by slumping. Near Newport on Yaquina Bay the formation dips westward at an angle of about 20 degrees and strikes from N. 3° W. to N. 16° W. The Nye formation consists of at least 2000 feet of a black, massive shale or claystone that upon exposure readily slacks to a black mud and normally occurs as slumps, especially where undercut by the sea. The shale contains but little grit and frequently can be identified by the presence of foraminifera, brown-colored fish scales and a meager invertebrate fauna. These shales occasionally enclose thin layers of concretionary sandstones or thin beds of calcareous sandstones.

The overlying marine Miocene of the Newport region has never been described in detail nor given a formation name. For the purposes of this paper it may be referred to as the "Astoria Miocene beds of the Newport region." Such a designation carries no implication that the entire Astoria formation, as developed typically at Astoria, Oregon, is present at Newport, but follows Howe (1926, p. 306) who correlated these rocks with the lower Astoria, known as the *Aturia* sandstones. These rocks occur principally along the ocean front between Yachats and Otter Rock in this section of the Oregon Coast. The few isolated outcrops south of Yaquina Bay include Seal Rocks, both the north and south shores of lower Alsea Bay, and a few localities between that bay and Yachats.

Between Yaquina Bay and Yaquina Head the Miocene occurs in the bolder sea cliffs, beneath the shifting sands of the beach and also as low strike reefs below the low-tide mark. At Yaquina Head these rocks pass beneath basaltic agglomerates and flows, unconsolidated Pleistocene, or Recent deposits. They reappear along the beach north of that promontory, occurring as truncated strike ridges or forming the nearly vertical cliffs developed by wave-action. They also outcrop in cuts along the Roosevelt Highway at several localities between Spencer Creek and Otter Rock.

This distribution is significant since within the strip thus described are all of the definite localities from which fossil marine mammals have been found, with the exception of University of Oregon locality 1150, which is within Yaquina Bay in rocks presumed to be of Yaquina age. The remaining localities, which have been inadequately described, undoubtedly also must be included within the area of outcrop of Miocene rocks, since, as shown below, a very definite zone of fossiliferous concretionary sandstones containing bone is now known to occur at a number of localities between Alsea Bay and Otter Rock.

The base of these Miocene sedimentary rocks has been recognized at several localities such as Arch Rock, Jump-off-Joe, near Nye Beach, at the mouth of Big Creek, and at Johnson Creek just north of Spencer Creek.

The top of these Miocene rocks may be seen at a few places such as at Yaquina Head where the resistant basalts, comprising that conspicuous promontory, have protected the marine sediments from the full attack of the waves. On the south side of that headland the marine sandy shales are overlain unconformably by agglomerates and intruded by feeders to the lava flows that lie immediately above. These have baked the sediments at the contacts and in places have carried fossiliferous shale inclusions up into the overlying igneous flows.

Massive dark-colored shales (Diller, 1896, p. 473) containing fish scales and a meager Oligocene invertebrate fauna underlie the Miocene sandy shales and sandstones. The overlying sediments contain shale inclusions at "Arch Rock," near Nye Beach, back of Jump-off-Joe, and near Johnson Creek. These shale inclusions obviously are derived from the Nye shale and they decrease in number and size in the beds higher up in the Miocene series. Similar conditions prevail farther north near Johnson Creek, wherever the contact happens to lie at the base of the present sea-cliff. The Nye shale gives little indication of its true structure at any of these known localities. Therefore the nature of the unconformity between the Nye shales and the Astoria has not been precisely determined.

The structure of the Miocene is such that higher and higher beds are encountered in going from Nye beach along the shore toward Yaquina Bay and in a similar way in passing from a point near the mouth of Big Creek toward Yaquina Head. North of Yaquina Head the configuration of the coast and the structure is such that successively lower beds are encountered in passing northward to the vicinity of Spencer Creek. The total thickness of these beds has not been ascertained.

The general structure of the Astoria rocks is monoclinal, the strike quite closely paralleling the trend of the present shoreline except for minor irregularities due to the resistance offered by such hard rocks as basalts or the massive Miocene sandstones. The Alsea Bay Miocene is represented by Schenck as striking from N. 7° W. to N. 65° W., and dipping westward about 20 degrees. Farther north at Seal Rocks the strike is N. 10° E., and the average dip is about 15 degrees. North of Yaquina Bay the strike is somewhat oblique to the trend of the shore. At Nye Beach the strike is N. 5° E., with a dip of about 10 degrees, thus making it possible to estimate the position of the cetothere skeleton found at University of Oregon locality 1151 as being very near the base of the Miocene beds. North of Jump-off-Joe the beds strike N. 10° E. and dip westward from 12 to 20 degrees. North of an oblique fault at the neck of Yaquina Head the strike shifts westward by about 10 degrees. At the mouth of Spencer Creek the beds may be seen to gradually shift from a north and south strike to N. 5° W. This apparent curvature of the structure may actually be seen by following with the eye the more resistant layers exposed on the beach northward toward Otter Rock. At the Devil's Punch Bowl the strike is N. 20° W. Just north of that shoreline feature, the Miocene tilts northward and plunges beneath the talus of agglomerates and lavas constituting the bold front of Cape Foulweather.

These Miocene rocks consist of sandstones and sandy shales usually occurring in beds not over 20 feet in thickness, except in the upper portion of the section at Otter Rock and possibly also at Seal Rock. The lower sandstones are typically blue-gray medium-grained rocks that are in places tuffaceous, or may be feldspathic or even glauconitic. Near the base they contain shale fragments evidently derived from the underlying Nye formation. These lower beds also contain large, hard, calcareous or sandstone concretions. These frequently are several feet in diameter and weather-out as large rounded masses that accumulate along the storm beach. These concretions are often fossiliferous, containing, for example, masses of *Arca devincta* Conrad, large pectens such as *Pecten propatulus* Conrad, or other invertebrates. They are also the source of much fossil mammalian material. The Crawford skull of *Desmostylus cymatias,* two cetothere crania, the recently discovered radius of a large mammal, the skull of *Desmatophoca oregonensis,* as well as many vertebræ, fragments of cetothere mandibles and ribs or other indeterminate bones have been found in concretions. Coarse-grained light-colored sandstones, containing rounded pebbles of igneous or other rocks and much fossil wood occur at Seal Rock, at Yachats and in the higher beds observable at Otter Rock. These show cross-bedding and rarely contain marine invertebrates.

Coarse to fine sandy shales constitute a large proportion of these Miocene sediments. These shales are dark colored, micaceous, readily weathered, and oxidize to a reddish brown. They contain small concretions or concretionary layers which are often fossiliferous. They can usually be distinguished from the Nye shales by their more sandy nature, the absence of fish scales, and on the basis of the fauna that occurs in most of the horizons.

A fine-grained tuffaceous shale, nearly white in color, occurs in the lower part of the section west of Newport and at a few localities farther north.

The overlying post-Astoria agglomerates and basaltic flows, and the intrusives, now form the prominent headlands like Cape Foulweather, Yaquina Head, Seal Rocks and similar features farther south. These resistant rocks have been beveled by wave action along with the soft Miocene sediments and have been uplifted to form the several raised beaches so typical of this coastal region. Upon these ancient beaches lie thick deposits of dark clays, dune sands or stream gravels. These are, in part at least, of Pleistocene age and are the probable source of proboscidean teeth reported from the present beach. Overlying these presumed Pleistocene deposits, there may be a thin veneer of humus that often partially conceals ancient Indian shell mounds, or in favorable places well-developed small sand dunes.

INVERTEBRATE FAUNA OF THE OLIGOCENE AND MIOCENE OF THE NEWPORT REGION

The Oligocene invertebrate fauna of Oregon has been the subject of several papers by Schenck. The oldest fauna from the Toledo formation is relatively meager and has no bearing upon this study. The fauna of the Yaquina formation is of possible significance since centra of a large mammal, presumably a whale, were found at University of Oregon locality 1150 in rocks believed to be of Yaquina age. A few of the more characteristic species from those beds include:

Acila shumardi Dall
Bruclarkia columbiana (Anderson & Martin)
Callianassa porterensis Rathbun
Cardium lincolnensis Weaver
Eucrate martini Rathbun
Fusinus lincolnensis Weaver
Macrocallista pittsburgensis Dall
Modiolus restorationensis Van Winkle
Mursia yaquinensis Rathbun
Patinopecten sp.
Portunites triangulum Rathbun
Thracia condoni Dall
Zanthopsis vulgaris Rathbun

The fauna of the Nye shales is meager, including such species as *Acila gettysburgensis* Reagen, *Acila* n. sp. Schenck, *Bruclarkia gravida* (Gabb), foraminifera and fish scales.

The Astoria Miocene invertebrate fauna of Oregon has long been the subject of investigation, study and comment by many investigators whose works have been reviewed or referred to by Howe (1926, p. 306), Schenck (1928, p. 28), and more recently by Etherington (1931, p. 48).

The following Mollusca have been collected from exposures of the Astoria formation on the coast of Oregon at points between Cape Foulweather on the north and the Moore Bros. ranch located 2 miles south of the entrance to Yaquina Bay. This list has been furnished through the courtesy of Dr. Hubert G. Schenck of Stanford University, Dr. Leo G. Hertlein of the California Academy of Sciences, and Dr. Charles Merriam of the University of California.

Partial List of Fossil Mollusks from the Astoria Formation (Middle Miocene) of Lincoln County, Oregon[1]

SPECIES	LOCALITY NUMBER	DIAGNOSIS OF LOCALITY	OTHER OCCURRENCES IN LINCOLN CO.	SPECIES LISTED BY ETHERINGTON FROM ASTORIA FORMATION OF WASHINGTON	REPOSITORY OF TYPE SPECIMENS WHERE KNOWN	TYPE LOCALITY
PELECYPODA						
Acila (Truncacila) conradi (Meek), 1864	C.A.S. 33	Between Johnson and Spencer Creeks	Agate Beach; 3 mi. north of same; also SW ¼ Sec. 6, T. 11 S., R. 11 W.	X	Paratype, U. S. Nat. Mus. No. 3526	Astoria, Ore.
Arca (Arca) devincta Conrad, 1849 ……	N.P. 14	Between Cape Foulweather and Otter Rock	U.C. 10002, between Yaquina Head and Cape Foulweather U.C. 3330, ocean cliff ¼ mi. south of Agate Beach U.C. 3331, ocean cliff 1 mi. north of Agate Beach C.A.S. 27656, ½ mi. S. of Yaquina Head	X	Holotype, U. S. Nat. Mus. No. 3499	Astoria, Ore.
Arca (Arca) osmonti Dall, 1909 ……….	C.A.S. 27659	4 miles north of Yaquina Bay			Holotype, Univ. Calif. Mus. of Paleo., No. 11927	Unknown
Chione (Chione) ensifera (Dall), 1909	C.A.S. 27657	Jump-off-Joe; 25 yards west of ocean cliff, ½ mi. north of Nye Cr.	C.A.S. 27653, 2 mi. S. of Yaquina Bay C.A.S. 27654, 2 mi. N. of Yaquina Bay U.C. 3336, ocean cliff in front of Moore Bros. ranch; 2 mi. S. of entrance to Yaquina Bay U.C. 10015, Jump-off-Joe, near Newport, Oregon C.A.S. 27660, 2 mi. S. of Newport	X	Type, U. S. Nat. Mus. No. 3611	Astoria, Ore.
Lucina acutilineata Conrad, 1849 …….	C.A.S. 27652	¼ mi. north of Yaquina Bay	C.A.S. 36, sea cliff ½ mi. N. of Cape Foulweather C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek C.A.S. 37, sea cliff ¼ mi. N. of lighthouse on Cape Foulweather	As *Phacoides acutilineatus*	"U. S. Nat. Mus. 3519 (Types of *acutilineata*)." According to Dall 1909.	Astoria, Ore.

Macoma arctata (Conrad), 1849	U.C. 3336	Ocean cliff in front of Moore Bros. ranch; 2 miles south of entrance to Yaquina Bay	½ mi. S. of Yaquina Head C.A.S. 38, sea cliffs just south of Cape Foulweather C.A.S. 39, sea cliff S. of Nye Beach, N. of entrance to Yaquina Bay C.A.S. 34, sea cliff between Spencer Creek and Wade Creek	X	Holotype, U. S. Nat. Mus. No. 3849	Astoria, Ore.
"Modiolus" directus Dall, 1909	N.P. 27	2 mi. south of Yaquina Bay	Between Cape Foulweather and Otter Rocks	X	Type, U. S. Nat. Mus. No. 153947	Coos Bay, Ore.
Nucula washingtonensis Weaver, 1916	C.A.S. 27653	2 mi. south of Yaquina Head		X	Calif. Acad. Sci. Type 449A	Univ. Wash. loc. 230, Grays Harbor Co., Wash.
Nuculana astoriana Henderson, 1920= *Yoldia impressa* (Conrad.)	C.A.S. 27653	2 mi. south of entrance to Yaquina Bay	C.A.S. 42, at Rocky Point 4 mi. E. of Yaquina City		Type, U. S. Nat. Mus.	Astoria, Ore.
Nuculana (Nuculana) chehalisensis (Weaver), 1912	C.A.S. 27653	2 mi. south of entrance to Yaquina Bay	C.A.S. 37, sea cliff ¼ mi. N. of lighthouse on Cape Foulweather	X	Calif. Acad. Sci. Syntypes 539, 540	Washington Geol. Survey loc. 63, Grays Harbor Co., Wash.
Panope (Panope) generosa Gould, 1850 (of authors) ..	U.C. 330	Agate Beach	C.A.S. 27656, ½ mi. south of Yaquina Head C.A.S. 39, sea cliff south of Nye Beach, north of entrance to Yaquina Bay C.A.S. 36, ½ mi. north of Cape Foulweather, about 4½ mi. north of Newport	X	?	"Puget Sound, Oregon" (Wash.)

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[1] The "U.C." numbers refer to collecting localities by H. V. Howe. "N.P." refers to locality number of H. Hannibal. "C.A.S." refers to the California Academy of Sciences, San Francisco, Calif.

Partial List of Fossil Mollusks from the Astoria Formation (Middle Miocene) of Lincoln County, Oregon[1]—Continued

Species	Locality Number	Diagnosis of Locality	Other occurrences in Lincoln Co.	Species listed by Etherington from Astoria formation of Washington	Repository of Type Specimens Where Known	Type Locality
Pecten (Chlamys) fucanus Dall, 1898 ..	C.A.S. 27653	2 mi. south of Yaquina Bay		X	Holotype, U. S. Nat. Mus. No. 107790	Clallam Bay, south shore of Fuca Strait, Wash.
Pecten (Patinopecten) propatulus Conrad, 1849	C.A.S. 27654	2 mi. north of Yaquina Head	C.A.S. 35, sea cliffs S. of Wade Creek, about 6 mi. north of Newport C.A.S. 36, sea cliff ½ mi. north of Cape Foulweather C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek, about 8 mi. N. of Newport		Holotype, U. S. Nat. Mus. No. 3504	Astoria, Ore.
Solen curtus Conrad, 1848 (of authors)	C.A.S. 38	Sea cliffs just south of Cape Foulweather	½ mi. south of Yaquina Head	X		Astoria, Ore.
Spisula (Mactromeris) albaria (Conrad), 1848	C.A.S. 27655	¼ mi. north of Otter Rock	N.P. 14, 2 mi. south of Otter Rock C.A.S. 38, sea cliffs just south of Cape Foulweather C.A.S. 37, sea cliff ¼ mi. north of lighthouse at Cape Foulweather	X	Type, U. S. Nat. Mus.	Astoria, Ore.
Tellina albaria Conrad, 1849	C.A.S. 27656	½ mi. north of Yaquina Head			Type, U. S. Nat. Mus. No. 3614 According to Dall 1909	Astoria, Ore.
Tellina (Moerella) obruta Conrad, 1848..	C.A.S. 27656	½ mi. north of Yaquina Head	C.A.S. 34, sea cliff between Spencer Creek and Wade Cr.	As *T obrupta.*	?	Astoria, Ore.

Tellina (Peronidia) oregonensis Conrad, 1848	C.A.S. 27656	½ mi. south of Yaquina Head	C.A.S. 36, sea cliffs ½ mi. N. of Cape Foulweather	X	?	Columbia River, near Astoria, Ore.
Venerella (Compsomyax) oregonensis (Conrad), 1848	C.A.S. 27653	2 mi. south of entrance to Yaquina Bay	C.A.S. 35, 36, 38, 39, (See above). U.C. 3336, Ocean cliff in front of Moore Bros. ranch; 2 mi. south of entrance to Yaquina Bay	? As *Marcia angustifrons*	?	Astoria, Ore.
Venericardia (Cycocardia) subtenta (Conrad), 1849	C.A.S. 27653	Ocean cliff in front of Moore Bros. ranch; 2 mi. S. of entrance to Yaquina Bay	C.A.S. 35, sea cliffs S. of Wade Creek, about 6 mi. N. of Newport	X	Holotype, U. S. Nat. Mus. No. 3502	Astoria, Ore.
GASTROPODA						
Argobuccinum dilleri Anderson & Martin, 1914	C.A.S. 35	Near mouth of Wade Creek	C.A.S. 27653, 2 mi. S. of entrance to Yaquina Bay, and 4½ mi. north of same C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek		Calif. Acad. Sci. Type 152	C.A.S. 35
"Bathytoma" condonana Anderson & Martin, 1914	C.A.S. 39	½ mi. north of Yaquina Bay		As *Pseudotoma condonana*	Calif. Acad. Sci. Type 214	C.A.S. 39
Bruclarkia oregonensis (Conrad), 1848	C.A.S. 27656	½ mi. south of Yaquina Head		X	Lost. Plesiotypes Univ. Calif. 31991-31994	Astoria, Ore.
Cancellaria rotunda Anderson & Martin, 1914	C.A.S. 39	½ mi. north of Yaquina Bay	C.A.S. 27656, ½ mi. S. of Yaquina Head		Calif. Acad. Sci. Types 205 and 206	C.A.S. 39
Calliostoma pacificum Anderson & Martin, 1914	C.A.S. 36	6 mi. north of Yaquina Bay	C.A.S. 27654, 2 mi. N. of Yaquina Head	X	Calif. Acad. Sci. Type 134	C.A.S. 36

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Partial List of Fossil Mollusks from the Astoria Formation (Middle Miocene) of Lincoln County, Oregon[1]—Continued

SPECIES	LOCALITY NUMBER	DIAGNOSIS OF LOCALITY	OTHER OCCURRENCES IN LINCOLN CO.	SPECIES LISTED BY ETHERINGTON FROM ASTORIA FORMATION OF WASHINGTON	REPOSITORY OF TYPE SPECIMENS WHERE KNOWN	TYPE LOCALITY
Crepidula prærupta Conrad, 1849	C.A.S. 27654	2 mi. north of Yaquina Head	C.A.S. 37, sea cliff ¼ mi. north of lighthouse on Cape Foulweather	X	Types, U. S. Nat. Mus. Nos. 3496 and 3564	Astoria, Ore.
"Drillia" antiselli Anderson & Martin, 1914	C.A.S. 27656	½ mi. south of Yaquina Head		As *Clathrodrillia (Moniliopsis) antiselli*	Calif. Acad. Sci. Type 226	Kern River, Calif.
"Drillia" buwaldana Anderson & Martin, 1914	C.A.S. 27656	½ mi. south of Yaquina Head			Calif. Acad. Sci. Types 223, 224, 225	Kern River, Calif.
"Eudolium" petrosum (Conrad), 1849	C.A.S. 27659	4 mi. north of Yaquina Head	C.A.S. 34, sea cliff between Spencer Creek and Wade Creek		Cotypes, U. S. Nat. Mus. No. 3536	Astoria, Ore.
Eulimella dilleri Anderson & Martin, 1914	C.A.S. 37	4 mi. north of Yaquina Bay			Calif. Acad. Sci. Type 140	C.A.S. 37
Ficus (Ficus) modestus (Conrad), 1848	U.C. 3330	Agate Beach	C.A.S. 34, sea cliff between Spencer and Wade Creeks, 7 to 8 mi. N. of Newport C.A.S. 27656, ½ mi. S. of Yaquina Head C.A.S. 39, sea cliff south of Nye Beach, N. of entrance to Yaquina Bay	X	Type lost	Astoria, Ore.
Haminoea petrosa (Conrad), 1849	C.A.S. 27656	½ mi. south of Yaquina Head	C.A.S. 34, sea cliff between Spencer and Wade Creeks, 7 to 8 mi. north of Newport	As *Cylichna petrosa.*	Holotype, U. S. Nat. Mus. No. 3607	Astoria, Ore.

"Miopleiona" indurata (Conrad), 1849	U.C. 3336	Otter Rock	N.P. 14, 2 mi. south of Yaquina Bay C.A.S. 35, sea cliffs S. of Wade Creek C.A.S. 33, sea cliff between Johnson and Spencer Creeks		Type U. S. Nat. Mus. No. 5908 According to Dall 1909.	Astoria, Ore.
"Nassa" lincolnensis Anderson & Martin,	C.A.S. 39	½ mi. north of Yaquina Bay	C.A.S. 27656, ½ mi. south of Yaquina Head		Calif. Acad. Sci. Type 167.	C.A.S. 39
Polinices reclusianus Deshayes, 1839 (of authors)	C.A.S. 27656	½ mi. south of Yaquina Head			?	Recent, Calif.
Sinum scopulosum (Conrad), 1849	C.A.S. 36	About 4½ mi. N. of Newport	C.A.S. 35, sea cliffs south of Wade Creek, about 6 miles N. of Newport C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek	X	Cotypes, U. S. Nat. Mus. No. 3553	Astoria, Ore.
"Trichotropis" oregonensis (Conrad), 1865. (Probably a *Cancellaria.*)	C.A.S. 27656	½ mi. south of Yaquina Head			"U. S. Nat. Mus. No. 3554. (figured type), 3549, and 3531." According to Dall 1909.	Astoria, Ore.
Trophon kernensis Anderson, 1905	C.A.S. 27659	4 mi. north of Yaquina Bay			Type, Calif. Acad. Sci. No. 73	Kern River, Calif.
Trophon oregonensis Anderson & Martin, 1914	C.A.S. 38	4 mi. north of Yaquina Bay	C.A.S. 36, sea cliff ½ mi. N. of Cape Foulweather C.A.S. 34, sea cliff between Spencer Creek and Wade Cr. C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek		Calif. Acad. Sci. Type 176	C.A.S. 38

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[1] The "U.C." numbers refer to collecting localities by H. V. Howe. "N.P." refers to locality number of H. Hannibal. "C.A.S." refers to the California Academy of Sciences, San Francisco, Calif.

Partial List of Fossil Mollusks from the Astoria Formation (Middle Miocene) of Lincoln County, Oregon[1]—Continued

Species	Locality Number	Diagnosis of Locality	Other occurrences in Lincoln Co.	Species listed by Etherington from Astoria formation of Washington	Repository of Type Specimens Where Known	Type Locality
Trophosycon kernianus (Cooper), 1894	C.A.S. 27658	Sea cliffs just north of Jump-off-Joe.			?	Kern County, Calif.
"Turris" carlsoni Anderson & Martin, 1914	C.A.S. 36	6 mi. north of Yaquina Bay	C.A.S. 38, sea cliffs just south of Cape Foulweather C.A.S. 37, sea cliffs ¼ mi. north of lighthouse at Cape Foulweather C.A.S. 36, sea cliff ½ mi. north of Cape Foulweather C.A.S. 34, sea cliff between Spencer and Wade Creeks, 7 to 8 mi. north of Newport		Calif. Acad. Sci. Type 212	C.A.S. 36
"Turris" lincolnensis Anderson & Martin, 1914	C.A.S. 36	6 mi. north of Yaquina Bay			Calif. Acad. Sci. Type 211	C.A.S. 36
Turritella oregonensis (Conrad), 1865	U.C. 3332	Ocean cliff 1 mi. south of Otter Rock	C.A.S. 33, sea cliff between Johnson and Spencer Creeks U.C. 3333, Jump-off-Joe; 25 yd. west of ocean cliff, ½ mi. north of Nye Creek		U. S. Nat. Mus. No. 110446 According to Dall 1909.	Astoria, Ore.
Scaphopoda						
Dentalium petricolum Dall, 1909	C.A.S. 27654	2 mi. north of Yaquina Head	3 mi. south of Yaquina Bay C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek C.A.S. 34, sea cliff between Spencer Creek and Wade Cr., 7 to 8 mi. N. of Newport		Holotype, U. S. Nat. Mus. No. 3481	Astoria, Ore.
Dentalium conradi Dall, 1909	C.A.S. 36	Sea cliff ½ mi. N. of Cape Foulweather	C.A.S. 33, sea cliff between Johnson Creek and Spencer Creek	X	"U. S. Nat. Mus. 3481 (part)." According to Dall, 1909.	Astoria, Ore.
Brachiopoda						
Terebratulina unguicula (Carpenter), 1864 ..	C.A.S. 27659	4 mi. north of Yaquina Bay				Recent, Vancouver Island

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[1] The "U.C." numbers refer to collecting localities by H. V. Howe. "N.P." refers to locality number of H. Hannibal. "C.A.S." refers to the California Academy of Sciences, San Francisco, Calif.

The following statement submitted by R. M. Kleinpell, of Stanford University, includes a list of the foraminifera identified from a sample of Astoria shale collected by Harold Hannibal from locality N. P. 273, at Astoria, Oregon, "in the hills back of the town from thirteenth street west to first street," and his interpretation of the relation of this horizon to certain Miocene deposits in California.

Anomalina (?) sp.	Rare
Cibicides floridanus (Cushman) ?	Rare
Dentalina pauperata d'Orbigny	Few
Orbulina universa d'Orbigny	Rare
Robulus americanus Cushman var. *spinosus* Cushman	Rare
Robulus nikobarensis Schwager var. *warmani* Barbat and von Estorff	Few
Siphogenerina branneri (Bagg)	Few
Siphogenerina transversa Cushman	Rare
Sphæroidina bulloides d'Orbigny?	Rare

This assemblage corresponds most closely to that of the *Uvigerinella obesa* zone, as defined by Kleinpell in an unpublished manuscript on Miocene Foraminifera from California. This zone equals the "Upper Member" of Cushman and Laiming[1] at the type locality of the Rincon shale in Ventura County, California. The zone has been recognized at the type area of the Temblor formation, Kern County, California, between the Carneros sandstone member[2] of this formation and the "button bed" (with *Scutella merriami*). Finally, the same *Uvigerinella obesa* zone is in the lower 400 feet of the Salinas shale in Reliz Canyon, Monterey County, where the shale conformably overlies the type Vaqueros formation. The zone falls within the limits of the *Turritella ocoyana* zone, as used by the molluscan palæontologists, but the foraminiferal zone is a more precise unit, as may be appreciated from the fact that the *Uvigerinella obesa* zone occupies the shale immediately above the "Barker's Ranch" sands on Kern River and occurs below the "diatomite" which, in turn, occurs below the "bone bed" at the same locality.

The sandy shale matrix surrounding the skeleton of the Newport cetothere from the southeast ¼ of section 7, township 11 south, range 11 west, yielded *Bolivina advena* Cushman, *Cassidulina lævigata* d'Orbigny, *Globulimina pyrula* (d'Orbigny), *Nonion costiferum* (Cushman), and *Nonion incision* Cushman ?. This small, poorly preserved faunule is Miocene in age. The foraminiferal evidence does not conflict with the molluscan which shows that this

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[1] J. A. Cushman and B. Laiming, 1931, Jour. Paleont., vol. 5, No. 2, 79-120.

[2] A name used first by H. G. Schenck and F. E. von Estorff in a manuscript for the "main reef" of the type Temblor. The term has crept into the literature and is now fairly well known by local stratigraphers.

sandstone is to be correlated with beds in California carrying the well-known "Barker's Ranch" megafauna.

The assemblages of Foraminifera from different levels in the uppermost part of the Nye shale near Newport, Lincoln County, Oregon, do not constitute a rich nor a well-preserved fauna, nor do they include many stratigraphically diagnostic species other than a number which may be referred roughly to the lower Miocene, as that term is now used in Pacific Coast stratigraphy.

Check list of some of the foraminifera from the Nye shale near Newport, Lincoln County, Oregon[1]

Species	Astoria sandstone			
	At contact with	3 feet below	5 feet below	15 feet below
Bolivina advena Cushman	C	C	C	C
**Bolivina marginata* Cushman	R	F		R
**Buliminella curta* Cushman	R	R		
Buliminella subfusiformis Cushman	F		F	
**Cassidulina lœvigata,* var. *carinata* Cushman	R	R		
Glandulina lœvigata d'Orbigny	R ?		R	
Globigerina bulloides d'Orbigny			R	F
Lagena perlucida (Montagu)				R
**Nodogenerina* cf. *advena* Cushman and Laiming		F	R	R
Nonion costiferum (Cushman)	R	R	R	F
Nonion incisum (Cushman)?	R		R	R
**Plectofrondicularia miocenica* Cushman			R	
Sphœrodina bulloides d'Orbigny		R ?	R	
Uvigerina cf. *auberiana* d'Orbigny	R	F	F	R
Uvigerinella obesa, var. *impolita* Cushman and Laiming	R	R	F	
**Virgulina bramlettei* Galloway and Morey	C	R	C	F

[1] Samples collected by H. D. Hobson near "Jump-off-Joe"; identifications by R. M. Kleinpell, Stanford University; May 1933. C, common; F, few; R, rare.

The closest affinities of the Nye shale Foraminifera are with the fauna from the "Middle Member" of the Rincon shale in Los Sauces Creek, Ventura County, California, as described by Cushman and Laiming. Five, possibly six, of the species (starred in the check list), in addition to such long-range forms as the *Glandulina, Globigerina, Lagena* and *Sphœroidina,* are known to range as low as the Oligocene, and three others are known from the lowermost Miocene, but such forms as *Nonion costiferum* and *Bolivina advena* are not known from horizons older than those represented by the "Middle Member" of Cushman and Laiming. Both of the two last-named species, as represented in the Nye shale, are on the whole smaller than the typical forms, but otherwise they appear to be typical. The *Plectofrondicularia* has a somewhat more bluntly truncated periphery than the type of Cushman's *miocenica,* but similar variants are known from the Lower Miocene of California. The *Uvigerina* is distinct from any of the species thus far recorded from the Pacific Coast.

That the fauna is not younger than that of Cushman and Laiming's "Middle Member" is indicated by the presence of *Uvigerinella obesa* var. *impolita;* most of the other forms range higher in the column but the species characteristic of the various younger horizons are entirely lacking in the Nye shale assemblages. In conclusion, the Foraminifera from the Nye shale identified above suggest that the strata carrying them are close in age to, and not younger than, the beds carrying the "Barker's Ranch" molluscan assemblage in Kern County, California.

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KNOWN OCCURRENCES OF FOSSIL MARINE MAMMALS IN THE NEWPORT REGION

The following specimens of fossil marine mammals have been obtained from the Tertiary of the Newport region.

1. *Desmatophoca oregonensis* Condon.

Condon, Thomas. A new fossil pinniped (*Desmatophoca oregonensis*) from the Miocene of the Oregon Coast. Univ. Oregon Bull., vol. 3, suppl. 3, pp. 14, figs. 3, pls. 2. May 1906.

Type specimen—Skull and mandible, as well as undescribed limb bones. Cat. Nos. 953, 932, 933, and 934, Condon Museum, University of Oregon (Type series, Nos. 306, 307, 308). [The tibia and fibula from the Miocene of Tillamook, Oregon, bear the Condon numbers 468 and 469.]

Type locality—From the "Miocene shales along beach just west of town of Newport, Lincoln County, Oregon." Locality[1] 1153, University of Oregon.

Horizon—Astoria formation, Middle Miocene.

2. *Desmostylus cymatias* Hannibal.

McCornack, Ellen Condon. A study of Oregon Pleistocene: The Oregon *Desmostylus* skull. Univ. Oregon Bull., n.s., vol. 12, No. 2, pp. 3-4, fig. 1. Oct. 1914.

Hay, O. P. A contribution to the knowledge of the extinct sirenian *Desmostylus hesperus* Marsh. Proc. U. S. Nat. Mus., vol. 49, pp. 381-397, pls. 56-58. Aug. 31, 1915.

Hannibal, Harold. Notes on Tertiary sirenians of the genus *Desmostylus*. Jour. Mammalogy, vol. 3, No. 4, pp. 238-240, pls. 11-12. Nov. 1922.

Type specimen—Skull. Cat. No. 8191, U. S. National Museum.

Type locality—"Chiselled out of sandstone at the mouth of Spencer Creek"[2] which is three miles north of Yaquina Head.

Horizon—The sandstones exposed at the mouth of Spencer Creek are definitely known to be Astoria Miocene.

3. *Desmostylus ? cymatias* Hannibal.

Merriam, J. C. Notes on the genus *Desmostylus* of Marsh. Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, No. 18, p. 406. 1911.

Hay, O. P. A contribution to the knowledge of the extinct sirenian *Desmostylus hesperus* Marsh. Proc. U. S. Nat. Mus., vol. 49, 381-382, 395. Aug. 31, 1915.

Referred specimen—A single molar tooth. Cat. No. 433, Condon Museum, University of Oregon (Type series, No. 309).

Locality—Listed in the Condon catalogue as coming from "Yaquina Coast," but Merriam stated that it came from "Yaquina Bay." Condon may have meant the ocean front, since Yaquina was the principal town in Condon's day and not Newport, as at present.

Horizon—If the specimen came from Yaquina Bay, it probably was derived from an Oligocene formation. If it came from the ocean front, the probabilities are in favor of a Miocene age rather than Oligocene.

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[1] Unpublished notes from Mrs. McCornack state that the seal was found eight miles south of Spencer Creek. This is less than one mile from the type locality of *Cophocetus oregonensis*.

[2] An unpublished note from Mrs. McCornack states that this skull was found by J. G. Crawford near Otter Rocks on the Oregon Coast.

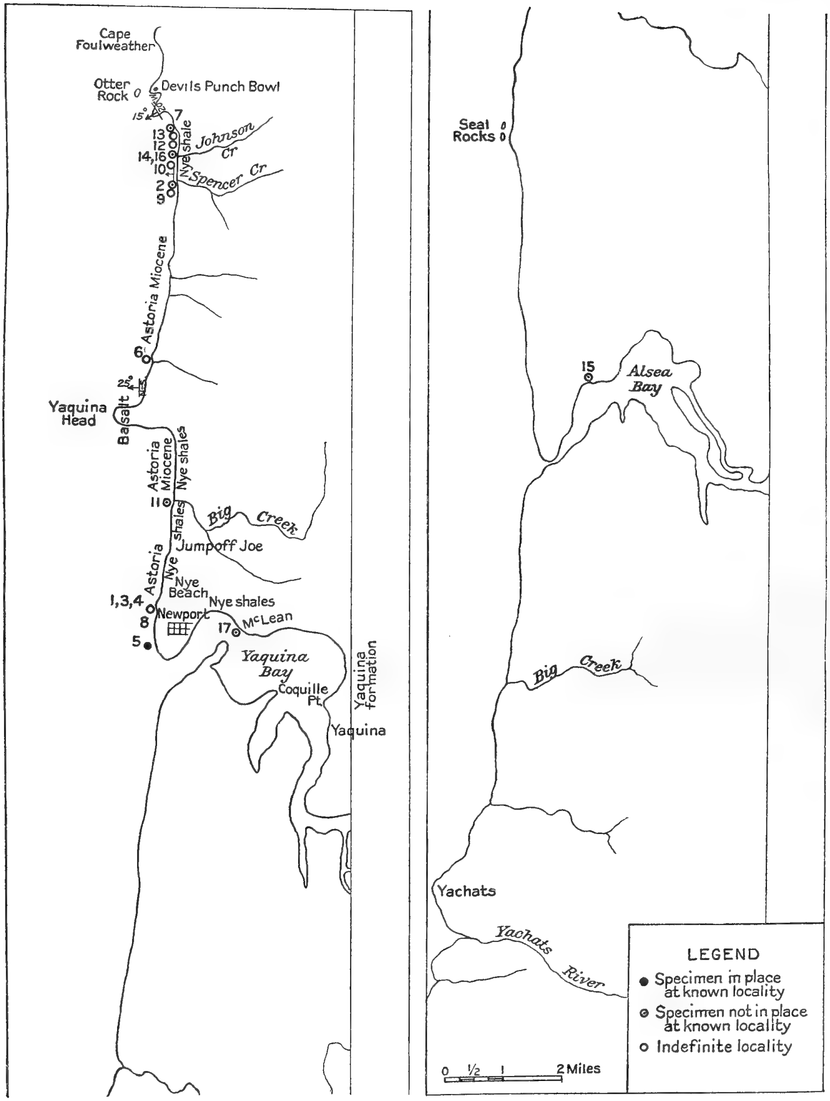

Fig. 1—Map of a portion of Oregon Coast between Yachats and Cape Foulweather, showing approximate localities of fossil marine mammals. For explanation of numerals see pages 20-22.

4. *Desmostylus ? cymatias* Hannibal.

Referred specimen—An undescribed molar tooth with six columns. Cat. No. 432, Condon Museum, University of Oregon (Type series, No 310).

Locality—The Condon catalogue records this specimen as coming from "Yaquina Coast Miocene."

Horizon—Probably the Astoria Miocene.

5. *Cophocetus oregonensis* new species.

Packard, E. L. (Abstract.) Bull. Geol. Soc. Amer., vol. 32, 148. 1921.

Remarks—This cetothere is described in the present paper (see p. 24).

6. *Cophocetus oregonensis* new species.

Referred specimen—An imperfectly preserved cranium collected by Dr. Eugene Callaghan. Cat. No. 311, Condon Museum, University of Oregon.

Locality—In a large concretion found on beach at Schooner Point, just north of Yaquina Head, Oregon.

Horizon—Since the Astoria Miocene alone is exposed at that locality, it probably came from the Astoria Middle Miocene.

7. *Cophocetus oregonensis*, new species (see p. 61).

Referred specimen—An imperfectly preserved cranium. Private collection of Mr. J. C. Snyder, Otter Rock, Oregon.

Locality—In a concretion found on beach near Otter Rock, Oregon.

Horizon—Astoria Middle Miocene.

8. Cetotheriidæ.

Specimen—An undescribed vertebra in the Condon Museum labeled in Ellen Condon McCornack's handwriting as coming from Yaquina Coast. That usage apparently meant the ocean front to Condon, as is also indicated by a block of matrix containing undoubted Miocene invertebrates and labeled by Condon as coming from the "Yaquina Coast."

9. Cetotheriidæ.

Hay, O. P. A contribution to the knowledge of the extinct sirenian *Desmostylus hesperus* Marsh. Proc. U. S. Nat. Mus., vol. 49, p. 382. Aug. 31, 1915.

Specimens—Two imperfect vertebræ. Apparently lost.

Locality—Presumably associated with the Crawford *Desmostylus* skull.

Horizon—Probably Astoria Middle Miocene.

10. Cetotheriidæ.

Specimens—Undescribed vertebræ in the Condon Museum, University of Oregon.

Locality—Collected by Eugene Callaghan along the beach north of Spencer Creek about one mile south of Otter Rock at University of Oregon locality 1154.

Horizon—Astoria Middle Miocene.

11. Cetotheriidæ.

Specimens—Undescribed vertebræ in the Condon Museum, University of Oregon.

Locality—Collected by Earl L. Packard in front of a sea-cliff composed of Miocene sediments at mouth of Big Creek south of Yaquina Head, Oregon. University of Oregon locality 1155.

Horizon—Astoria Middle Miocene.

12. Cetotheriidæ.

Specimens—More than fifty vertebræ in the private collection of Mr. J. C. Snyder of Otter Rock, Oregon, and a lesser number in private collection of Mr. N. H. Sherwood of Otter Rock, Oregon.

Horizon—Astoria Middle Miocene.

13. Cetotheriidæ.

Specimens—Many short pieces of mandibles, the largest hardly more than six inches in length, in private collections of Messrs. Snyder and Sherwood of Otter Rock, Oregon.

Horizon—Astoria Middle Miocene.

14. Undetermined mammal.

Specimens—A series of vertebræ and ribs found in two large concretions on the beach and about 100 feet apart. Type series, No. 312, Condon Museum, University of Oregon.

Locality—Concretions lying on the beach in front of cliff of concretionary Astoria Miocene at University of Oregon locality 1152, about 600 feet north of Johnson Creek and about 1 mile south of Otter Rock, Oregon.

Horizon—Astoria Middle Miocene.

15. Marine vertebrate.

Schenck, H. G. Stratigraphic relations of western Oregon Oligocene formations. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 18, No. 1, 34. Nov. 30, 1928.

Specimen—Fragments of bone collected by Dr. Hubert H. Schenck.

Locality—At Schenck's locality A-201, plotted on map (*op. cit.*, p. 33) as on the north shore of Alsea Bay, northwest of Waldport, Oregon.

Horizon—Reported by Schenck as the base of the Astoria Miocene.

16. Undetermined mammal.

Specimen—An undescribed radius. Type series, No. 313, Condon Museum, University of Oregon.

Locality—University of Oregon locality 1152 (see 14).

Horizon—Astoria Middle Miocene.

17. ? Cetacean.

Specimen—Eight poorly preserved vertebræ in the Condon Museum, University of Oregon.

Locality—At first prominent point above Newport on north side of Yaquina Bay and at low-tide mark on the beach. University of Oregon locality 1150. Collected by Earl L. Packard.

Horizon—Probably Yaquina Oligocene, since the matrix is lithologically nearer the Yaquina sandstone formation than the Nye shale and also since no Miocene deposits have been definitely reported from Yaquina Bay.

CORRELATION OF THE MAMMALIAN HORIZONS OF THE NEWPORT REGION

The age of the Tertiary sediments on the Oregon Coast has attracted the attention of a number of geologists and palæontologists who have expressed a rather wide range of opinion. Schenck has reviewed a number of papers concerned with correlations based upon invertebrate faunas and has presented their conclusions in the form of a correlation table. Arnold and Hannibal called attention to three invertebrate faunas in the Oregon Oligocene. Harrison and Eaton recognized the three stratigraphic divisions which were faunally justified and defined by Schenck. The two lower Oligocene stages were correlated by Schenck with other Oregon faunal facies and also with the Lincoln-Porter horizon of Washington. The Nye fauna was considered at first as probably Oligocene, but that age has been questioned by Schenck[1] who raised the question: "Is the Nye shale the Oregon equivalent of the Vaqueros formation of California?"

The "Astoria shales" were first considered Miocene by Condon; then Oligocene by Dall and by Arnold; Monterey Miocene by Arnold and Hannibal; and Temblor Miocene by Clark, Howe, Schenck and Etherington. The "Aturia bed" of Dall and Harris was first referred to the Eocene, then to the Oligocene by Dall and finally to the Miocene by Howe, Schenck and Etherington. Etherington[2] concludes that the Astoria sandstones and the overlying Astoria shales on the Oregon Coast are equivalent to the Middle Miocene Temblor and Topanga formations of California, and to the Astoria formation of Washington. This author states that, "The large percentage of Astoria species in the Temblor, in contrast to the small percentage in the Vaqueros below and the Briones above, confirms the prevailing correlation of the Astoria fauna with the Temblor of California. Howe, from a fauna of ninety-eight species from the Astoria formation of Oregon, found that 46 per cent of them were common to the Temblor of California." Howe considered the Astoria invertebrate fauna to be contemporaneous with the "Barker's Ranch fauna of the Temblor."

Etherington[3] compares the Astoria fauna from Washington with Atlantic Coast and European faunas and concludes: "These comparisons apparently show that the Astoria formation is middle Miocene in age and that it can be tentatively correlated with the Helvetian of Europe." Kellogg[4] has recorded a fauna of marine mammals

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[1] H. G. Schenck, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 16, 458. Mar. 19, 1927.

[2] T. J. Etherington, *Stratigraphy and fauna of the Astoria Miocene of southwest Washington,* Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 20, No. 5, 54, 55, May 20, 1931.

[3] *Op. cit.,* 56.

[4] R. Kellogg, *Pelagic mammals from the Temblor formation of the Kern River region, California,* Proc. Calif. Acad. Sci. (4), vol. 19, No. 12, 217-397, figs. 134, Jan. 30, 1931.

from the bone bed of the Kern River Temblor which he has considered as Helvetian. Other indirect evidence that the Temblor formation is Middle Miocene in age is obtained from Merriam's[1] conclusions in regard to the land vertebrates found in the *Merychippus* zone near Coalinga, California.

Inasmuch as the Astoria formation of Oregon has been correlated with the Temblor[2] formation of California, one might expect to find the same cetotheres in both formations, in view of the known geographic ranges of recent mysticetes. The Newport cetothere, however, is readily distinguishable from the Temblor species. One explanation that may be offered is that the Astoria invertebrate fauna has been compared with the Barker's Ranch fauna of the Temblor, and this horizon is stratigraphically considerably below the upper bone bed with its fauna of pelagic mammals. Three cetotheres, *Tiphyocetus temblorensis, Peripolocetus vexillifer* and *Parietobalæna ? securis,* have been recognized in the fauna from the Temblor bone bed.

Rather inconclusive evidence as to the age of the Astoria sandstones and shales in the Newport region is afforded by the marine vertebrates. The seal *Desmatophoca oregonensis,* the peculiar *Desmostylus cymatias,* and the cetothere hereinafter described represent Miocene stages in their respective groups. The three species of marine mammals here represented have not as yet been recognized in other formations of Miocene age. Therefore, the only direct evidence as to the age of the Astoria sandstones of the Newport region is that afforded by the presence of identical or related Foraminifera and the larger Mollusca in them and in the Barker's Ranch zone of the Temblor formation of the Kern River region, California.

COPHOCETUS[3] new genus

Genotype—Cophocetus oregonensis new species.

Diagnosis—Apex of supraoccipital shield thrust forward beyond level of anterior ends of zygomatic processes; nasals located in part anterior to

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[1] J. C. Merriam, *Tertiary vertebrate faunas of the North Coalinga region of California,* Trans. Amer. Philos. Soc., n.s., vol. 22, pt. 3, 26, 1915.

[2] The term "Temblor" is so loosely defined as to have little precise connotation. Detailed studies at the type area of the Temblor formation in Kern County, California, by numerous stratigraphers, clearly prove that by original definition the Temblor comprises strata deposited during a considerable lapse of time. Kleinpell (in an unpublished paper) shows that the lower 1000 ± feet of the type Temblor is to be correlated with the upper 1000 ± feet of the type Vaqueros formation, Monterey County, California. The "button bed" (with *Scutella merriami*), by original definition the top of the type Temblor formation, is definitely younger than the foraminiferal shales which on Kern River overlie the sands carrying the "Barker's Ranch" megafauna. The Topanga formation of Los Angeles County is considered, on molluscan evidence, to be the correlative of the Temblor, but this formation includes in its upper part a foraminiferal fauna even younger than the foraminiferal equivalent of the "button bed." R. M. Kleinpell.

[3] **Κωφός** blunt; *κῆτος* whale—in allusion to the blunt extremity of the rostrum of the skull.

level of preorbital angles of supraorbital processes; thin anterior process of parietal, which overrides basal portion of supraorbital process, not extended forward to level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries, and the nasals); backward thrust of rostrum has carried hinder ends of median rostral elements to or beyond level of center of orbit, but not to level of anteriormost portion of hinder edge of supraorbital processes of frontals; a short and rather narrow intertemporal constriction formed by parietals; exposure of frontals in median interorbital region reduced to a narrow strip; rostrum relatively broad, not displaying any pronounced attenuation distally; zygomatic processes robust and directed forward; alisphenoid present in temporal wall of braincase. Condyle of mandible broad, not laterally compressed, and possessing a deep furrow on internal face near ventral border. Periotic characterized by transverse expansion of the denser dorsal portion and its prolongation upward into cerebral cavity, a short anterior process with outwardly projected postero-ventral angle, and an unusually large and broad fossa on cerebral face in region of orifice of vestibular aqueduct.

Humerus with head of moderate proportions and with rugose curved crest along anterior or radial edge of shaft. Manus with five digits, the third being the longest. Hinder lumbars with high broad neural spines. Distal ends of transverse processes of hindermost lumbar not modified to function as sacral. Innominate bone with elongated ilium, shortened ischium and a laterally compressed sub-triangular pubis.

Cophocetus oregonensis new species

Type—Cat. No. 305, Department of Geology, Condon Museum, University of Oregon, Eugene, Oregon; locality No. 1151, Department of Geology. The specimen consists of the major portion of the skull, the left zygomatic process and the outer ends of both supraorbital processes being destroyed. The tympanic bullæ and the periotic bones were attached to the skull. The anterior ends of both mandibles are destroyed. Portions of both fore limbs including the scapulæ, left humerus, both ulnæ, four carpals, six metacarpals and eighteen phalanges were found alongside the vertebral column. The vertebræ include six cervicals, eleven more or less complete dorsals, seven lumbars and five caudals. Both innominate bones were found below the hindermost lumbar. A few imperfectly preserved ribs were associated with this skeleton.

Type locality—On ocean beach near level of high-tide mark about 1000 feet northwest of the old Tower (C. G. 128) at Newport, Lincoln County, Oregon. Southeast ¼ of Section 7, Township 11 South, Range 11 West, Willamette base and meridian.

Horizon—A fissile sandy shale belonging to the Astoria formation, which has been correlated with the "Barker's ranch fauna" of the Temblor formation (Miocene) in California. The specimen was discovered and collected by Earl L. Packard in 1920.

SKULL

This skull is characterized chiefly by the absence of any pronounced attenuation of the rostrum, by an obvious forward thrust of the supraoccipital and the parietals and a more pronounced backward thrust of the median rostral elements, a short intertemporal constriction, a very limited exposure of the frontals in the median interorbital region, temporal fossæ relatively short antero-posteriorly and wide transversely, a broad dorsal narial fossa, short robust zygomatic and postglenoid processes, and large palatines.

Dorsal view—When viewed from the dorsal side (fig. 2), attention is at once directed to the large sub-triangular occipital shield, the small occipital condyles, the depression of the dorsal surface of the squamosal behind the base of the zygomatic process, and the presence of a fairly well-marked transverse temporal crest on each supraorbital process. The rostrum is characterized by its relatively great width throughout its length and constitutes about 64 per cent of the total length of the skull.

Although the maxillaries are not complete, it is possible to reconstruct their outlines with a fair degree of accuracy, since the original lateral edge is present on the major portion of the right maxillary, including a short section in the region of the antorbital notch. The restored portions of the external borders of the maxillaries shown on plate 2 represent the impressions left on the matrix by the original surfaces. These bones are very broad and become quite thin along their external margins. They appear to show a slight arch longitudinally, but this may have resulted from distortion of the rostrum. The dorsal ascending process of the maxillary appears to extend posteriorly slightly beyond the level of the hinder ends of the premaxillaries. Coextensive with the nasals at least, the inner border of the maxillary is overlain by the premaxillary. Laterally, the posterior end of the maxillary overrides the preorbital border of the frontal. The restoration of the postero-external angles and the curvature of the antorbital notches is somewhat conjectural, since the outer edge of the hinder portion of the right maxillary is complete posteriorly only as far as the point where this edge commences to curve, forming the antorbital notch. At least two foramina of medium size are present in each maxillary opposite the nasals and at a level 10 to 15 mm. external to the maxillary-premaxillary suture. The internal face of the hinder portion of each maxillary abuts against the outer surface of the trough-like vomer.

In front of the vomer, each premaxillary curves downward and inward to meet its fellow on the mid-line of the rostrum. The vomer behind and the premaxillaries in front thus contribute the floor and the sides of the dorsal narial gutter. The long slender premaxillaries attain their maximum width at the level of the anterior ends of the maxillaries. The dorso-internal edges of the opposite premaxillaries parallel one another from the extremity of the rostrum to the anterior end of the dorsal narial gutter, where they are bent downward and are curved outward and then inward to conform to the contour of this fossa. The slightly narrower ascending or facial process of the premaxillary is lodged in a shallow groove which follows the dorso-internal edge of the hinder end of the maxillary and it terminates at the level of the posterior ends of the nasal bones. The posterior extremity of this element is also lodged in grooves on the narial process of the frontal. The dorsal surface of the premaxillary in front of the dorsal narial fossa shows a slight convexity in a transverse plane, and anteriorly it projects forward beyond the maxillary.

On this skull the backward thrust of the median portion of the rostrum has not carried the ascending processes of the maxillaries and premaxillaries, as well as the nasals, much beyond the level of the center of the orbit.

The dorsal narial fossa is deep, elongate and quite broad, the maximum transverse diameter at a point about 210 mm. in front of the hinder ends of

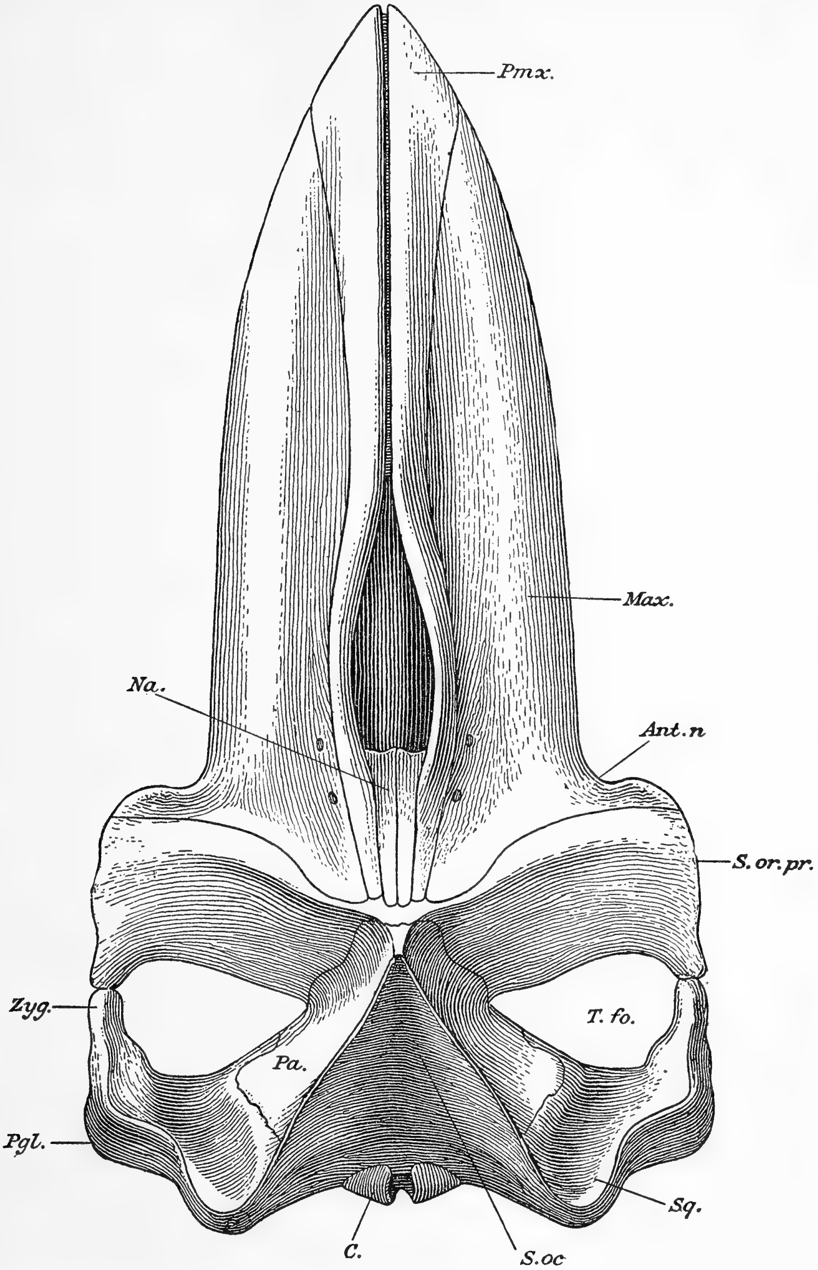

FIG. 2—Dorsal view of skull of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Missing portions restored. ⅛ nat. size.

Abbreviations: ***Ant. n.,*** antorbital notch of maxillary; ***C.,*** occipital condyle; ***Ext. a. m.,*** channel for external auditory meatus; ***Ex. oc.,*** exoccipital; ***f. ov.,*** foramen ovale; ***J. n.,*** notch for jugular leash; ***L. pr.,*** lateral process of basioccipital; ***Max.,*** maxillary; ***Na.,*** nasal; ***O. c.,*** optic canal; ***Pa.,*** parietal; ***Pal.,*** palatine; ***P. gl.,*** postglenoid process; ***Pmx.,*** premaxillary; ***P. pr.,*** posterior process of periotic; ***Pt.,*** pterygoid; ***S. oc.,*** supraoccipital; ***S. or. pr.,*** supraorbital process of frontal; ***Sq.,*** squamosal; ***T. fo.,*** temporal fossa; ***Ty.,*** tympanic bulla; ***Zyg.,*** zygomatic process of squamosal.

the nasal bones being 76 mm. The maximum antero-posterior diameter of this fossa is approximately 250 mm.

The relatively long nasal bones taper toward their posterior ends and are wedged in between the ascending processes of the premaxillaries. Their hinder ends are mortised into the narial process of the combined frontals and anteriorly they overhang the dorsal narial fossa. The nasals may possibly project backward slightly beyond the level of the hinder ends of the maxillaries and the premaxillaries, but this is somewhat uncertain, since their original surfaces have been destroyed at this point. The antero-external angles of the nasals, likewise, may possibly project forward as wings beyond the medial portions of these elements since the anterior ends of both nasals are incomplete medially, and furthermore the medial line of contact between them is quite indistinct.

The frontals are very narrowly exposed in the median interorbital region and are excluded from the vertex by the parietals. They present a median exposure of approximately 25 + mm. between the hinder ends of the overriding rostral elements and the intertemporal constriction formed by the parietals. The frontal slopes regularly from the interorbital region toward the orbital rim of the supraorbital process, and also slopes obliquely downward behind the fairly well-marked transverse temporal crest. The outer portions of the supraorbital processes, as far as can be judged from this specimen, apparently were somewhat flattened. Unfortunately, the outer ends of both supraorbital processes are destroyed and the reconstructions are therefore hypothetical. The anterior margin of the supraorbital process, which on the left side is complete about halfway to the external margin, is concealed by the hinder end of the maxillary. The hinder margin of the supraorbital process is constructed upon evidence obtained from the right side, on which this margin is complete for approximately one-third of its probable length. If such a reconstruction may be accepted as approximately correct, the supraorbital process is rather broad antero-posteriorly. The median rostral elements override the anterior medial border of the frontals to an unknown extent. Posteriorly the frontals are suturally united with the parietals at the anterior end of the intertemporal constriction. The rostral wall of the cranium is formed largely by the frontals.

The parietals, which meet medially to form a short intertemporal constriction, are overriden above and behind by the large triangular supraoccipital shield. This short intertemporal constriction, unfortunately, is eroded, and hence the exact nature of the vertex has been obliterated. Anteriorly, the thin narrow process of the parietal, which overrides the base of the supraorbital process, extends forward far beyond the level of the hinder margins of the supraorbital processes, but not quite to the level of the hinder ends of the ascending processes of the maxillaries. The parietal, as a whole, is a broad bone lying for the most part below the lambdoidal crest and constituting the major portion of the nearly vertical lateral wall of the braincase. Behind the level of the hinder edge of the supraorbital process, the lower edge of the parietal anteriorly is in contact suturally with the dorsal edge of the alisphenoid and, behind the latter, the suture between the parietal and the squamosal curves outward, then upward, and finally backward to meet the supraoccipital on the lambdoidal crest. The dorsal edge of the parietal also constitutes the overhanging outer face of the lambdoidal crest.

The squamosal is the large thick bone which constitutes the conspicuous postero-lateral portion of the skull. The very slightly convex and almost vertical anterior face of the squamosal, which constitutes the major portion of the hinder wall of the temporal fossa, curves backward and outward from the alisphenoid to the base of its zygomatic process. This surface is complete on the right side, but is imperfectly preserved on the left side. The hinder portion of the dorsal surface of the squamosal is conspicuously excavated, forming a large concavity which is bounded above, behind and outside by the lambdoidal crest. The squamosal and parietal, above the level of the zygomatic process, bulge outward along their sutural contact. The right zygomatic process is complete, with the exception of a short section of its anterior extremity. The left zygomatic process unfortunately is destroyed. This process is widened at the base and is directed more or less forward. Its distal end is somewhat flattened from side to side, and it also is narrowed dorsally to form a low longitudinal crest.

From a dorsal view, the occipital condyles appear to be flattened against the basicranium. The heavy exoccipitals project outward and backward beyond the level of the hinder surfaces of the occipital condyles and are not entirely hidden by the overhanging postero-external portion of the lambdoidal crest.

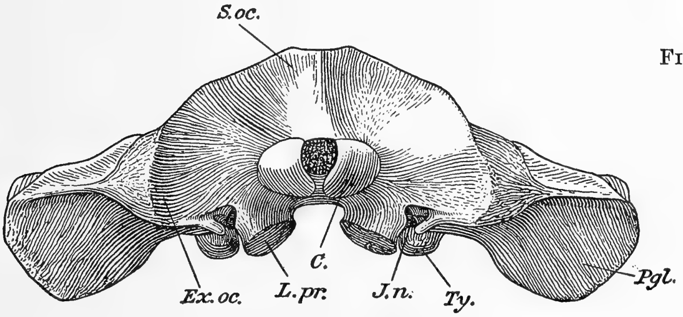

FIG. 3—Posterior view of skull of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. ⅛ nat. size. (For explanation of abbreviations, see fig. 2.)

The supraoccipital is quite broad at the base and is attenuated toward the apex. The distal portion of the supraoccipital shield is flattened and is slightly depressed below the lambdoidal crests. The forward thrust of the hinder elements in the cranium has carried the apex of the supraoccipital shield forward beyond the level of the anterior ends of the zygomatic processes.

Posterior view—The triangular shield, which forms practically the entire hinder wall of the braincase (fig. 3), consists of the medially depressed supraoccipital above and the large exoccipitals ventro-externally. Although both lambdoidal crests are eroded, sufficient remnants are preserved to show that on each side the crest curves upward and forward to the rather narrow apex. On each side, these lambdoidal crests are formed by the lateral edges of the supraoccipital and the abutting hinder edges of the parietal superiorly and the squamosal inferiorly.

The exoccipitals are fairly large massive bones and comprise the lateral wings of the posterior triangular occipital shield. These elements are thickened antero-posteriorly and their external angles project backward beyond the level of the condyles. The postero-external angles of both of the exoccipitals are eroded. No protuberant paroccipital process is developed. On each side of the median basicranial depression, a large lateral protuberance projects downward from the basioccipital and external to it is the large notch for the jugular leash. This notch is bounded internally by the outer wall of the lateral protuberance of the basioccipital, and above and externally by the exoccipital. A slender process of the exoccipital, which projects downward and inward, almost closes the ventral gap. The dorsal surface of this notch is traversed by two distinct grooves and they are directed obliquely outward and backward. The large rounded lateral protuberances of the basioccipital form a conspicuous part of the ventral profile.

The margins of the left occipital condyle are essentially complete, but the upper half of the right condyle is broken off. The articular surfaces of these condyles are slightly convex from end to end and less so from side to side. The condyles are separated ventrally by a narrow notch and are set off from the exoccipital surface by a very shallow groove. Although the upper margin of the foramen magnum is destroyed, there is some evidence to indicate that it was wider than high.

The rather large postglenoid process, which projects laterally beyond the outer edge of the exoccipital, extends ventrally considerably below the level of the basicranium.

The tympanic bullæ shown on figure 3 are not in their normal position, for their internal faces are flattened against the periotic in the tympano-periotic recess.

Lateral view—The apex of the supraoccipital shield forms the highest point in the dorsal profile and, in front of it, the dorsal margin of the short intertemporal and interorbital regions slope abruptly to the level of the hinder ends of the median rostral elements. From the hinder ends of the median rostral elements to the extremity of the rostrum, the dorsal profile slopes slightly downward and forward.

The rostrum is rather deep at the level of the anterior ends of the palatine bones and gradually decreases in depth anteriorly. The outer edge of the maxillary is quite thin throughout its length.

The peculiarities of the orbital end of the supraorbital process of the frontal are unknown for this specimen. The inner portion of the supraorbital process, however, slopes gradually outward and downward from the level of the median interorbital region.

The zygomatic process of the squamosal is quite deep dorso-ventrally and the curvature of the ventral profile is regularly concave from its anterior end to the extremity of its postglenoid process, while the dorsal profile rises gradually posteriorly. The hinder face of the postglenoid process seems to have been unusually flattened, judging from the basal half of this surface. The squamosal is rather large and constitutes a considerable portion of the lateral wall of the braincase. This element projects backward beyond the level of the hinder face of the postglenoid process and abuts against the antero-posteriorly thickened exoccipital.

The nearly vertical parietal contributes the major portion of the lateral wall of the braincase. It meets the one on the opposite side in front of the apex of the supraoccipital shield to form the short isthmus or intertemporal constriction which connects the occipital portion of the skull with the facial or interorbital portion. The dorsal and hinder edges of the parietal form a continuous curve which is overlain by the lateral edge of the supraoccipital shield, the apex of which projects forward beyond the level of the anterior ends of the zygomatic processes.

The occipital condyles are not visible when the skull is viewed from the side. The ventral profile of the palatine, viewed from the side, curves downward to the level of its contact with the pterygoid.

The alisphenoid appears on the temporal wall of the braincase as an irregularly shaped element behind the base of the supraorbital process and above the pterygoid. In the temporal fossa the alisphenoid is bounded dorsally and anteriorly by the parietal, posteriorly by the squamosal and ventrally by the pterygoid. The boundaries of the alisphenoid are quite distinct. The exposed surface of the outer end of the alisphenoid is more or less rhomboidal in outline, the greater length being in the antero-posterior direction (antero-posterior diameter, 55 mm.; vertical diameter, 33 mm.).

Ventral view—The under surface of this skull (fig. 4) is fairly complete, and areas that are imperfectly preserved on one side are generally good on the opposite.

The horizontally expanded maxillaries constitute the major portion of the palatal surface of the skull. On the hinder portion of the rostrum, the palatal surface of each maxillary is concavely curved from side to side, but exhibits a distinct tendency toward flattening distally, and throughout its length there is a downward and inward convex curvature where it is applied medially to the under surface of the trough-like vomer. There is also a series of shallow, narrow and slightly curved grooves which are directed forward in a more or less oblique direction from the inner to the outer margins of the palatal surface of this bone. The grooves on the hinder portion of the rostrum are quite short and are directed more obliquely outward. These vascular grooves supply the ligamentary tissues as well as the blades of baleen which are attached to the roof of the mouth. The hinder border of the maxillary was apparently thrust backward below the supraorbital process of the frontal almost to the level of the ventral channel for the optic nerve. The postero-external angles of the maxillaries are, as already mentioned, uncertain. Anteriorly, there is no positive evidence of the exposure of the premaxillaries on the ventral surface of the rostrum. At a point 330 mm. in front of the anterior ends of the palatines the inner margins of the maxillaries diverge slightly (the maximum interval at the point of widest divergence toward the anterior end of the rostrum does not exceed 11 mm.), exposing the median longitudinal ventral ridge of the vomer for a distance of at least 280 mm. Between the anterior end of the vomer and the anterior extremity of the rostrum, a distance of 150 ± mm., the premaxillaries meet ventrally along the median longitudinal axis of the rostrum to constitute a complete floor for the dorsal narial gutter. The trough of the vomer is widest at the level of the anterior ends of the palatines. The ventral ridge of the vomer is entirely concealed by the close approximation of the palatines for a distance of at least 240 mm. behind the level of the anterior ends of the latter. At this point the palatines commence to diverge from one another, exposing the internal choanæ. At this point, also, the vomer develops a 50-mm. high and 17-mm. wide (at palatal level) longitudinal carina, which constitutes the median partition between the internal choanæ. The ventral face of this carina extends backward at almost the same horizontal level for a distance of 54 mm. and then diminishes in height rather rapidly to its posterior end which coincides with the hinder end of the vomer. The horizontal distance from the hinder end of the vomer to the point of divergence of the palatines is 133 mm. The hinder horizontally expanded thin plate of the vomer is applied to the ventral surface of the basisphenoid and overrides the anterior border of the basioccipital; in front of the former it encircles the ventral and lateral surfaces of the presphenoid. Externally along each lateral margin this horizontally expanded plate of the vomer is suturally united with the vaginal process of the corresponding pterygoid.

The well-preserved palatines resemble somewhat in shape an elongated shield. They are closely approximated medially. The outer edge of each

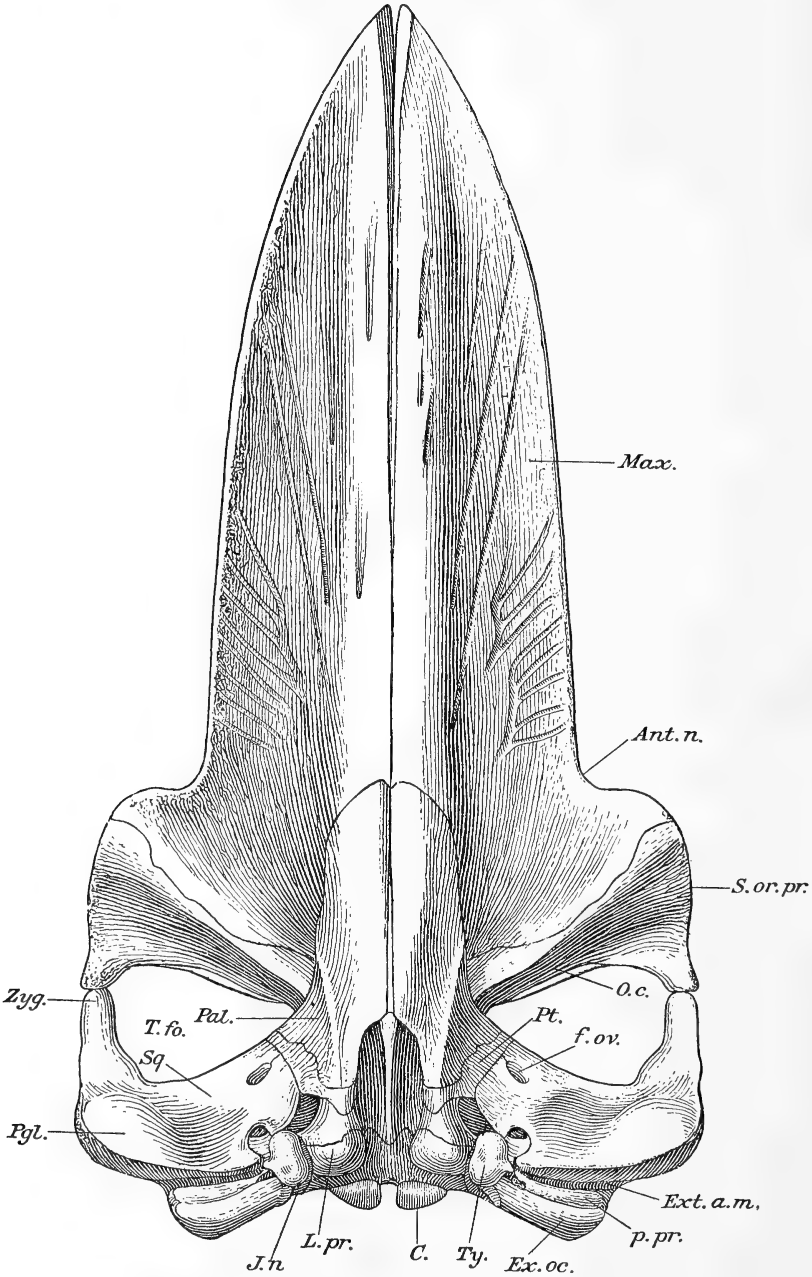

Fig. 4—Ventral view of skull of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Missing portions restored. ⅛ nat. size. (For explanation of abbreviations, see fig. 2.)

palatine is mortised into the internal border of the corresponding maxillary and rests upon the trough-like vomer. From the median line, the anterior half of each palatine slopes obliquely toward the dorsal edge in a gentle convex curvature. The anterior margin of each palatine is rounded while the external margin exhibits a slightly concave curvature. Externally, each palatine is bounded on the anterior half of its length by the maxillary. Behind this and for a distance of approximately 75 mm., it is apparently in contact with the under surface of the frontal and then contributes the ventral boundary of the optic foramen. Behind the postero-internal angle of the supraorbital process, the outer border of the palatine is ankylosed with the pterygoid on the inner wall of the temporal fossa. The thin posterior end of the palatine likewise overspreads the pterygoid below the anterior end of the pterygoid fossa. A prominent carina, which commences on the outer edge and near the level of the hinder end of maxillary, extends obliquely backward and inward across the ventral face of the palatine to its postero-internal angle. This carina marks the dividing line between the more or less horizontal ventral surface and the oblique lateral portion of the hinder end of the palatine which curves obliquely downward to the temporal margin.

The frontals are extended outward to form the expanded supraorbital processes. The channel for the optic nerve commences at the oval optic foramen and extends transversely across the under surface of the supraorbital process. Judging from the basal portion of the right process, the optic canal widens toward the orbital rim of the supraorbital process. Near its origin, this channel is limited to the hinder face of the supraorbital process and then is twisted downward until it is wholly upon the under surface of this process. This channel is bounded in front by a high thick crest and behind by a low carina which follows the hinder edge of the supraorbital process.

The basioccipital, viewed from the ventral side, is a rectangularly shaped bone with its long axis transverse to longitudinal axis of the skull. On each side, in front of and extending externally beyond the level of the occipital condyle, is a very large rounded lateral descending protuberance. These enlarged lateral protuberances of the basioccipital greatly reduce the transverse diameter of the median basicranial depression. The maximum transverse distance between the inner faces of these protuberances does not exceed 40 mm. The somewhat flattened external surfaces of these lateral protuberances slope obliquely downward and project outward for a short distance below the tympano-periotic recess. The basioccipital is ankylosed in front with the basisphenoid, the line of contact being overspread by the horizontally expanded posterior end of the vomer. The anterior face of each lateral protuberance is fused with the corresponding vaginal process of the pterygoid, but the line of contact can be determined on both sides. The ventral surface of this vaginal process of the pterygoid curves downward to conform to the curvature of the corresponding surface of the lateral protuberance.

The basisphenoid is a flat rectangular bone, the greater length being in the antero-posterior direction. It is entirely concealed by the thin horizontally expanded hinder plate of the vomer. Externally this element is suturally united on each side with the vaginal process of the pterygoid. It is separated in front by an open suture from the somewhat cylindrical presphenoid.

The vaginal process of the pterygoid is preserved in its entirety on the right side, but is incomplete on the left side. This process is suturally united along its dorsal edge with the outer edge of the basisphenoid. It meets or is ankylosed to the horizontally expanded hinder plate of the vomer along its dorso-internal margin. The hinder end of this vaginal process, as mentioned previously, is fused with the anterior surface of the lateral protuberance of the basioccipital. When complete these vaginal processes of the opposite pterygoids take part in the formation of the lower boundaries of the internal choanæ and, in conjunction with the lateral protuberances of the basioccipital, bound the median region of the basicranium.

The narrow and elongated pterygoid fossa, as its name implies, is bounded internally by the vaginal process of the pterygoid, anteriorly and antero-externally by the downward curvature of the thickened anterior and outer borders of the pterygoid, and postero-externally by the thick and rather large falciform process of the squamosal. The roof of this fossa is constituted by a thin plate of the pterygoid and the floor or ventral wall by the inwardly and backwardly curved hamular process of the pterygoid. On the right side, where this region is exceptionally well preserved, the hamular process, which curves backward and inward to form the floor for the pterygoid fossa, has been broken off and crushed downward into this fossa. It was broken off from the pterygoid at a level below and at a point about 15 to 18 mm. internal to the foramen ovale. In its original state, it was continuous externally with the portion of the pterygoid which appears in the temporal fossa between the anterior end of the falciform process of the squamosal and the base of the supraorbital process of the frontal. The pterygoid fossa is entirely hidden from a ventral view by the elements constituting its ventral wall. The hinder end of this pterygoid fossa is not closed over by any bony plate or process, but is continuous with the tympano-periotic recess. Behind the posterior edge of the hamular process of the pterygoid and in front of the tympanic bulla, and between the lateral protuberance of the basioccipital and the internal edge of the squamosal is an elongated aperture (antero-posterior diameter, 39 mm.; maximum transverse diameter, 19 mm.) which exposes a portion of the tympano-periotic recess.

The rather large tympano-periotic recess (transverse diameter, left side, 70 mm.; antero-posterior diameter, left side, 80 mm.) opens into the interior of the cranium. It is bounded by the squamosal and its falciform process externally, by the alisphenoid and underlying thin plate of the pterygoid anteriorly, by the lateral protuberance of the basioccipital internally, and by the exoccipital posteriorly.

The posterior lacerated foramen for the jugular leash occupies a narrow notch which is located at the postero-internal angle of the tympano-periotic recess. It is bounded by the lateral protuberance of the basioccipital internally and by the exoccipital externally and superiorly (transverse diameter of notch at ventral limit 9 mm.).

On the ventral surface, the contact between the squamosal and the exoccipital is concealed by the posterior process of the periotic which is wedged in between these two elements. Between the posterior process of the periotic and the base of the hinder face of the postglenoid process is a narrow transverse channel, which widens internally, for the external auditory meatus. This channel originates at the inner edge of the squamosal and extends outward almost at right angles to the longitudinal axis of the skull.

The right squamosal is fairly complete, except for the extremity of the zygomatic process. The ventral end of the postglenoid process also is incomplete. The curvature of the anterior surface of this postglenoid process, however, indicates that it projected when complete at least 50 mm. below the level of the lateral protuberances of the basioccipital. The postglenoid process is very robust, apparently with a relatively flat posterior face, an obliquely sloping anterior face and a rounded external face. The outer temporal margin of the squamosal as well as the entire zygomatic process, with the exception of the hinder basal portion of the postglenoid process, is destroyed on the left side. The right zygomatic process is attenuated from the base toward the extremity and its under surface exhibits a slight concave curvature from end to end. External to the anterior process of the periotic, the ventral surface of the squamosal is hollowed out, forming a large elongated concavity which extends forward obliquely from the postero-internal angle of the postglenoid process to near the glenoid angle of the squamosal and also downward upon the internal face of the postglenoid process. The maximum transverse diameter of this fossa on the right side is 65± mm. and its maximum longitudinal diameter is 110 mm. On the ventral side of the skull, the squamosal forms the outer and the major portion of the hinder boundaries of the temporal fossa, the internal margin being contributed by the outer edge of the palatine. External to the pterygoid fossa and behind the postero-external angle of the palatine is a large orifice, the foramen ovale. This foramen is located in the bifurcation between the falciform and glenoid processes of the squamosal. The anterior-posterior diameter of the foramen ovale is 30.5 mm. and its vertical diameter is 8.5 mm. The falciform process of the squamosal is strongly convex in both directions, and its internal border projects inward over a portion of the tympano-periotic recess, as well as over the hinder end of the pterygoid fossa. At the hinder end of this falciform process is a rather large foramen, which opens into the tympano-periotic recess (transverse diameter of foramen, 18 mm.; antero-posterior diameter of foramen, 11 mm.).

The large thickened exoccipitals constitute the hinder boundary of the ventral surface of the skull. The condyles are separated medially by a narrow notch.

Measurements of skull (in millimeters)

Greatest length of skull, anterior end of left premaxillary to posterior surface of left occipital condyle	1203+
Anterior end of left premaxillary to apex of supraoccipital shield	995+
Greatest length of left premaxillary	910+
Distance from anterior end of left premaxillary to anterior end of left nasal bone	742+
Distance from apex of supraoccipital shield to posterior end of right nasal bone	90±
Greatest length of right nasal bone	158
Combined width of nasal bones, anteriorly	71
Combined width of nasal bones, posteriorly	30
Transverse distance between outside margins of premaxillaries at level of anterior ends of nasal bones	110
Transverse distance between postero-internal angles of ascending processes of opposite maxillaries	62
Transverse diameter of rostrum at base, estimated	380±
Transverse diameter of skull across preorbital angles of supraorbital processes, estimated	580±
Distance across skull between outer surfaces of zygomatic processes, estimated	625±
Distance across skull between outer margins of exoccipitals	440
Maximum distance between outer margins of occipital condyles	124
Greatest or obliquo-vertical diameter of left occipital condyle	67
Greatest transverse diameter of left occipital condyle	52
Transverse diameter of foramen magnum	35±
Distance from upper margin of foramen magnum to apex of triangular supraoccipital shield	210±
Vertical distance from basisphenoid to apex of supraoccipital shield	165

Maximum length of right zygomatic process, extremity of postglenoid process to anterior end of zygoma	212±
Greatest breadth of basioccipital across lateral protuberances, outside measurement.	154±
Least intertemporal diameter of cranium on ventral face	186
Least intertemporal diameter of cranium on dorsal face	30
Distance from anterior end of right palatine to point of divergence of hinder edge from median line	240
Maximum antero-posterior diameter of right palatine, when complete, estimated	315±
Greatest transverse diameter of right palatine	90
Greatest transverse diameter of combined palatine bones	150
Greatest transverse diameter of left pterygoid fossa, anteriorly	41.5
Greatest transverse diameter of left pterygoid fossa, posteriorly	47
Least distance between opposite foramina ovale	223

TYMPANIC BULLÆ

Although both tympanic bullæ are preserved with the skull, the right one is shifted from its normal position and somewhat crushed, but the left one is essentially normal. The left bulla was removed for study and the following descriptions of the internal and dorsal aspects are based in part upon it.

The general shape of the bulla is pyruliform. In ventral aspect, the bulla is attenuated toward the anterior end and abruptly widened behind the middle of its length. The postero-external angle is more angular than the other two, which are more or less rounded. The ventral surface of the bulla is quite rugose and a broad shallow groove separates the postero-internal and postero-external angles.

The dorsal aspect of the bulla is modified somewhat by the sinuous curvature of the outer lip and the backward projecting posterior pedicle. The thick involucrum is relatively wide posteriorly, but is attenuated anteriorly. The internal profile of the bulla is nearly straight. The dorsal surface of the involucrum is somewhat flattened posteriorly, but anteriorly it is more noticeably convex from side to side and descends abruptly into the tympanic cavity. The dorsal face of the involucrum is also creased by low transverse ridges which flatten out on the internal border of the bulla.

The over-arching outer lip is irregularly curved from end to end and relatively thin. The posterior pedicle of the bulla projects mainly from the involucrum and to a lesser extent from the hinder angle of the outer lip. A narrow vertical fissure separates the portion of the pedicle which arises from the involucrum from the portion which projects from the outer lip. The short posterior conical apophysis is bluntly rounded and projects laterally beyond the level of the posterior pedicle. The sigmoid process, with the exception of its basal portion, is destroyed on the left bulla. It is complete on the right bulla. The basal portion of the sigmoid process is twisted on its axis so that its extremity is almost transverse to long axis of the bulla. The hinder face of this process is hollowed out behind and like most cetotheres has a distinctly convex anterior face. A rather deep and broad vertical groove is present on the outer lip of the bulla between the sigmoid process and the anterior pedicle. The anterior pedicle is unfortunately crushed against the outer lip of the left bulla, concealing most of its structural peculiarities. The thin outer lip is curved inward and arches over the *cavum epitympanicum* which is considerably longer than wide and curved from end to end.

Measurements of left tympanic bulla (in millimeters)

Maximum antero-posterior diameter	61±
Maximum transverse diameter	32
Maximum dorso-ventral diameter of involucrum	29.5

PERIOTICS

Aside from having a narrow and much more elongated posterior process, this periotic is structurally somewhat similar to that of *"Heterocetus" affinis* van Beneden.[1] The periotics of these two cetotheres are characterized by having a similar transverse expansion of their denser portions, a relatively short anterior process, ventro-external angle of anterior process projected conspicuously outward, orifice of vestibular aqueduct located in an unusually broad and deep fossa, hinder face of periotic deeply excavated above level of groove for facial nerve, and in addition the thickened dorsal portion prolonged upward into the cerebral cavity. The posterior process of *"Heterocetus" affinis* is short, curved and quite robust, but the cerebral prolongation of the denser dorsal portion is rounded in contrast to the bifurcated appearance of the same portion of the periotic of the Newport cetothere.

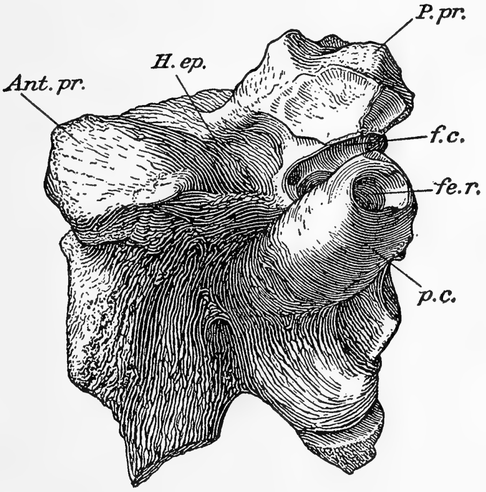

FIG. 5—Inferior view of left periotic of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Posterior process broken off and attached to skull. Nat. size.

Abbreviations: *Ant. pr.*, anterior process of periotic; *Aq.c.*, aquaeductus cochleae; *Aq.f.*, aquaeductus fallopii; *f. aq. v.*, fossa around entrance to aquaeductus vestibuli; *f.c.*, channel for facial nerve; *fe.r.*, fenestra rotunda; *H.ep.*, hiatus epitympanicus; *I. a. m.*, internal acoustic meatus; *p.c.*, pars cochlearis; *P. pr.*, posterior process of periotic broken off at this level.

The periotic of the Temblor cetothere, *Peripolocetus vexllifer*,[2] has a large swollen anterior process which is bent inward almost at right angles to the antero-posterior axis of the body of this bone. There are other structural peculiarities, including the shape of the fossa on the cerebral face surrounding the orifice of the aqueduct of the vestibule, which readily distinguish this periotic from that of the Newport cetothere. The periotics of *Tiphyocetus temblorensis*[3] and *Parietobalaena? securis*,[4] likewise from the Temblor formation in California, have been figured and require no discussion.

The posterior process of the Newport cetothere (fig. 4) is elongated, attenuated at both ends and relatively narrow antero-posteriorly. It is wedged in between the exoccipital and the squamosal, while the body of

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[1] P. J. van Beneden, 1886, *Description des ossements fossiles des environs d'Anvers.* Pt. 5. Genres: Amphicetus, Heterocetus, Mesocetus, Idiocetus & Isocetus. Ann. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, vol. 13, pl. 20, figs. 6, 9-13.

[2] R. Kellogg, 1931, *Pelagic mammals from the Temblor formation of the Kern River region, California,* Proc. Calif. Acad. Sci. (4), vol. 19, No. 12, 339-340.

[3] *Op. cit.,* 327-331, figs. 80-81.

[4] *Op. cit.,* 344-348, figs. 92-94.

the periotic comprising the cochlear and vestibular areas and the anterior process projects into the large recess behind the pterygoid fossa. The posterior pedicle of the tympanic bulla is ankylosed to the basal angle of the posterior process of the periotic. The external face of the denser portion of the periotic is quite rugose and is convex in both directions.

The *pars cochlearis* is relatively small and quite narrow; its tympanic surface is strongly convex and the external face overhangs the *fenestra ovalis*. The ventral profile (fig. 6) of the cochlear portion of the periotic viewed from the cerebral side is strongly arched, but descends abruptly to the *fenestra rotunda*.

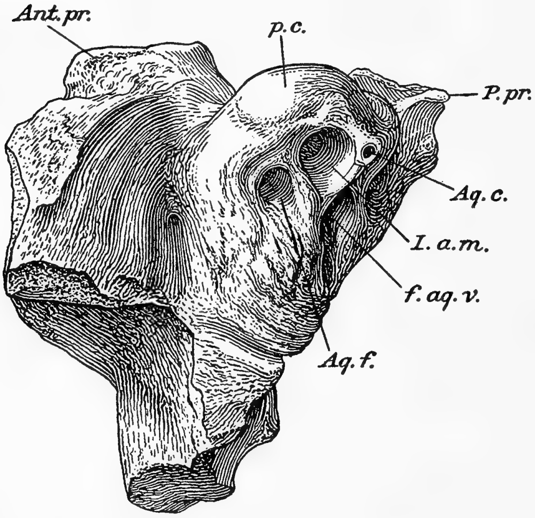


Fig. 6—Cerebral view of left periotic of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Posterior process broken off and attached to skull. Nat. size. (For explanation of abbreviations, see fig. 5.)

The *fenestra ovalis* is partially encircled by a narrow rim, which separates it from the narrow channel for the facial nerve and also from the fossa for the stapedial muscle. There is a deep and narrow groove leading forward from the anterior rim of the *fenestra ovalis* to the notch between the *pars cochlearis* and the anterior process. The channel for the facial nerve, between the epitympanic orifice of the *aquæductus Fallopii* and the level of the hinder end of the *fenestra ovalis*, is overhung by the thin inwardly projecting edge of the outer denser portion of the periotic. On this projecting edge there is a slight depression which may represent the small *fossa incudis*. Behind the level of the *fenestra ovalis*, the narrow channel for the facial nerve does not appear to have been set off from the shallow fossa for the stapedial muscle by any ridge, and posteriorly it curves outward around the hinder face of the basal angle of the posterior process. The stapedial fossa extends downward upon the external face of the *pars cochlearis* and terminates posteriorly at the emargination produced by the rather deep fossa on the hinder face of the periotic.

In front of and external to the epitympanic orifice of the Fallopian aqueduct is an unusually large and shallow fossa for lodging the head of the malleus. External to this fossa (fig. 5), the outer border of the ventral face is depressed, forming the *hiatus epitympanicus*. In front of the fossa for the head of the malleus, a remnant of the basal portion of the thin anterior pedicle of the tympanic bulla is ankylosed to the periotic. The ventro-external angle of the anterior process is conspicuously prolonged outward and the whole process is quite short.

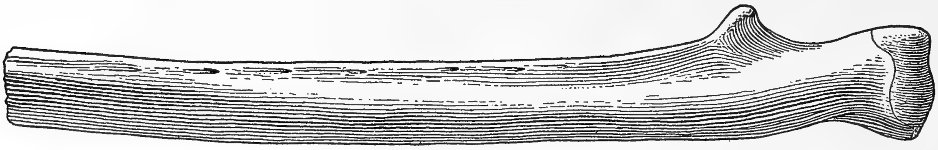
On the cerebral surface (fig. 6) and below the apex of the *pars cochlearis* the circular internal acoustic meatus is located. The spiral tract and the minute *foramen singulare* lie at the bottom of this tract. An osseous crest separates the entrance to the *aquæductus fallopii* from the larger and more centrally placed internal acoustic meatus. The rather small orifice for the aqueduct of the cochlea is situated in close proximity to, but behind the posterior margin of the internal acoustic meatus. Above the latter is a very broad fossa, extending upward from the narrow depression, which marks the position of the orifice of the aqueduct of the vestibule, for a distance of 20 mm. An unusually high (5 mm.) and quite thin osseous ridge separates this fossa from the internal acoustic meatus, and a somewhat thicker osseous crest is placed between this fossa and the deep excavation on the hinder face of the periotic above the level of the stapedial fossa.

Measurements of left periotic (in millimeters)

Breadth of periotic at level of *fenestra ovalis* (from external face above *hiatus epitympanicus* to internal face of *pars cochlearis*	30
Greatest length of posterior process (external wall of groove for facial nerve to extremity of process)	110±
Greatest transverse diameter of *pars cochlearis*	14.2
Greatest dorso-ventral depth of periotic (from most inflated portion of *pars cochlearis* and the *hiatus epitympanicus* to most dorsally projecting point on cerebral face)	58.5

Mandibles

The mandibles are quite well preserved, except for their anterior ends, which are missing. Fortunately, a cast was made of the impression of the symphysis at the time of excavation. The right mandible (pl. 2) is somewhat crushed between the coronoid process and the condyle, but the left mandible (fig. 7) seems to be normal in this region. From a dorsal view (fig. 9) these rami are rather noticeably bowed outward, especially near the middle of their length. The lateral view shows that they are also slightly bowed downward and that the vertical diameter decreases rather uniformly to the anterior end. This view also shows the low dorsal projection of the rounded and outwardly recurved coronoid process and the hinder profile of the condyle. A large fossa (fig. 8) which leads to the orifice of the mandibular canal is present on the internal face just anterior to the condyle and extends forward as far as the level of the coronoid process. This fossa is rapidly narrowed anteriorly. The mandibular canal decreases very rapidly in diameter from its origin to a point about 340 mm. anterior to hinder face of condyle, and at this level the canal is located in approximately the center of the ramus. From here on to the broken anterior end of the ramus, there is a relatively slight decrease in diameter of the canal. At the broken anterior end of the mandible, the small mandibular canal is quite near the superior margin of the ramus. The condyle in posterior aspect is irregularly elliptical, the longer axis being dorso-ventral. The posterior surface of the condyle is convex from side to side and slopes obliquely from about the middle of the hinder face to the upper and lower margins.



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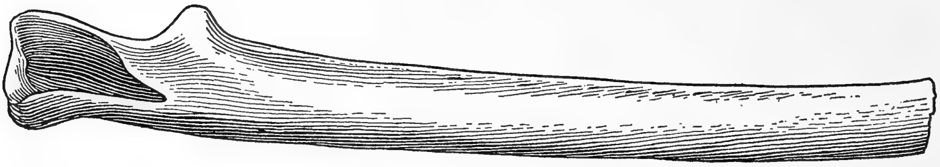

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Fig. 7—Lateral view of left mandible of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Anterior extremity missing. ⅛ nat. size.

Fig. 8—Internal view of left mandible of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Anterior extremity missing. ⅛ nat. size.

Fig. 9—Dorsal view of right mandible of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Anterior extremity missing. ⅛ nat. size.

Measurements of the mandibles (in millimeters)

	Right	Left
Greatest length of mandible in straight line when complete, estimated	1200	1200
Greatest length of mandible as preserved, in a straight line	950	935
Greatest length of mandible as preserved, along outside curvature	990	970
Greatest vertical diameter of mandible 130 mm. anterior to hinder face of condyle	76.5	
Greatest vertical diameter of mandible 300 mm. anterior to hinder face of condyle	91.5	
Greatest transverse diameter of mandible 300 mm. anterior to hinder face of condyle	61	
Greatest vertical diameter of mandible 460 mm. anterior to hinder face of condyle	78.5	
Greatest transverse diameter of mandible 460 mm. anterior to hinder face of condyle	61	
Greatest transverse diameter of mandible 740 mm. anterior to hinder face of condyle	50	
Greatest transverse diameter of mandible 920 mm. anterior to hinder face of condyle	44	
Greatest vertical diameter of mandible at coronoid process	135	
Greatest transverse diameter of condyle		.90

VERTEBRÆ

Seven cervical vertebræ were certainly present in the vertebral column. Assuming that the vertebral column consisted of 7 cervicals, 12 dorsals, 12 lumbars and 14 caudals, and computing the lengths of the centra of the missing vertebræ from the relative lengths of those that were found, it measured about 3.4 meters in length. The total length of the complete skeleton, including the skull, then approximated 4.6 meters.

CERVICAL VERTEBRÆ

The atlas is missing and the remaining six cervicals are incomplete, and in most instances are represented by the centra and the basal portions of some of the processes. The axis is sufficiently complete to permit a fairly accurate restoration (fig. 10). The neural arch and the left transverse process are destroyed. The odontoid process of the axis is fairly prominent and projects forward for a distance of 19 mm. The smooth ventral surface of this process is convex from side to side and rises obliquely to the apex from the inferior margin of the anterior face of the centrum. The dorsal surface of the odontoid process is continuous with the downward sloping superior surface of the centrum. Behind the apex and on the dorsal face of this process is a short obtuse ridge. The apex of the odontoid process is situated slightly below the level of a horizontal line drawn through the middle of the opposite articular facets. The right anterior articular facet and the right transverse process are essentially complete. The right facet is nearly flat dorso-ventrally (maximum diameter 65 mm.) and very slightly concave from side to side (distance from apex of odontoid process to external margin of facet, 62.5 mm.). The wing-like transverse process is directed outward and very slightly backward. It is quite thin antero-posteriorly and is attenuated toward its distal end. This process is per-

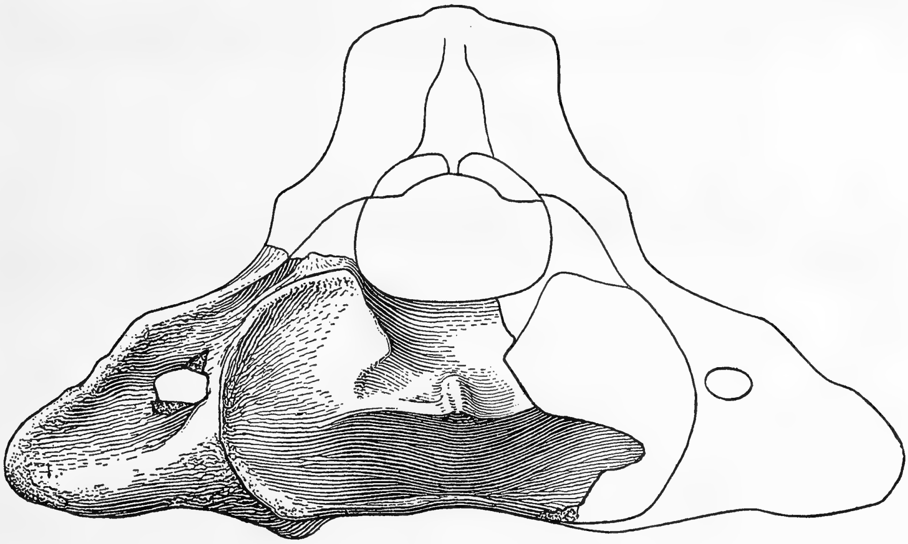


FIG. 10—Anterior view of axis of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Restored portion indicated by outline only. ½ nat. size.

forated at the base by an ovoidal *foramen transversarium,* which is rather small and is situated a little above the level of a median line drawn between extremities of opposite transverse processes. A broad groove extending from postero-external angle of neural canal to *foramen transversarium* crosses the hinder face of this process.

The antero-posterior diameters of the centra progressively increase from the third to the seventh cervicals, the diameter of the hinder one being about one-half greater than that of the third. The transverse diameter is greater than the vertical diameter of the centrum of the third cervical, but the hindermost centrum is more nearly circular in outline. The articular faces of most of the centra are smooth and there is no evidence of any ankylosis with one another. The basal portions of the left inferior transverse processes are well enough preserved to show in what direction they projected from the centra. It is also obvious that the ventral process on the left side of the sixth cervical is more noticeably flattened dorso-ventrally than the corresponding process of any of the preceding cervicals. No inferior transverse process, however, is developed on the right side of the sixth cervical. As in other known cetotheres, no inferior transverse processes are developed on the seventh cervical.

The right superior transverse process is partially preserved on both the fifth and the sixth cervicals. On each of these vertebræ, the process is strongly flattened antero-posteriorly, attenuated distally, and directed obliquely downward and backward. Judging from the dimensions of the basal portion, the superior transverse process of the seventh cervical, however, is rather robust and resembles that of the first dorsal. The neural arches of the five hinder cervicals have been broken off and the fragments preserved are too incomplete to permit restoration. Among these fragments are portions of the neural spines of the fourth and fifth cervicals.

Measurements of cervical vertebræ (in millimeters)

	3d	4th	5th	6th	7th
Maximum antero-posterior diameter of centrum	16.5	18	18.8	19.5	23.2
Maximum vertical diameter of centrum	66.5	x	68	70.5	69
Maximum transverse diameter of anterior face of centrum	73	x	70.8	70.5	66.5

DORSAL VERTEBRÆ

The vertebræ belonging to the dorsal series are all imperfectly preserved. Among the fragments of these dorsals, it is possible to recognize the more or less complete diapophyses and some of the centra of eight of the anterior dorsals, as well as the transverse processes of the three hindermost dorsals.

The first dorsal is represented by a nearly complete centrum and a portion of the neural arch, including the left diapophysis. The convex distal facet on the diapophysis for articulation with the tuberculum of the first rib measures 33 mm. antero-posteriorly and 20 mm. dorso-ventrally. The right postzygapophysial facet is convex from end to end and narrower than long, the maximum antero-posterior diameter being 21 mm. The centrum resembles that of the hindermost cervical in that it is rather wide and also conspicuously flattened antero-posteriorly. The lateral and ventral surfaces of this centrum are concave and are separated ventrally by a broad median longitudinal ridge. On the left side and below the base of the pedicle of the neural arch, a single large facet for articulation with the head of the corresponding rib extends obliquely across the lateral face of the centrum. On the right side of the centrum, the antero-superior facet does not appear to have been present and the postero-superior facet is relatively small. The basal portions of the pedicles of the neural arches are robust, but are narrower antero-posteriorly than the corresponding diameter of the centrum. The measurements are as follows: Maximum antero-posterior diameter, 27.5 mm.; maximum transverse diameter of anterior face, 76 mm.; and maximum vertical diameter of anterior face, 63.5 mm.

The second dorsal is represented by the centrum and the pedicles of the neural arch, but the distal ends of both diapophyses are destroyed. The lateral face of the centrum is concave from end to end, and possesses a large postero-superior facet for articulation with the head of the third rib. The measurements of the centrum are as follows: Length, 35 mm.; transverse diameter of anterior face, 81 mm.; and vertical diameter of anterior face, 62.5 mm. The pedicles of the neural arch and also the basal portions of the diapophyses are quite robust.

The third dorsal is likewise imperfectly preserved. The centrum is damaged, but measures 45 mm. in length. It possesses a distinct postero-superior facet on the lateral face for articulation with the head of the fourth rib. The left pedicle of the neural arch is quite robust, measuring 18 mm. antero-posteriorly. The postzygapophysial facets are flattened. The left diapophysis is complete and is characterized by its thin anterior edge and rounded hinder edge. It is expanded distally (antero-posterior diameter, 39 mm.) and contracted medially (minimum antero-posterior diameter, 20.5 mm.). The distance from the inner face of the left pedicle to the distal end of the left diapophysis is 91 mm. The distal facet for articulation with the tuberculum of the corresponding rib is concave from end to end and slopes obliquely downward and inward.

The fourth dorsal was not recognized among the various fragments associated with the dorsal vertebræ.

All of the processes are broken off of the centrum of the fifth dorsal. The centrum measures 47.5 mm. antero-posteriorly. The right diapophysis of this dorsal projects 74 mm. beyond the level of the external face of the pedicle of the neural arch. The distal facet, which articulates with the tuberculum of the fifth rib, is concave from end to end and slopes downward and inward. This diapophysis is compressed dorso-ventrally and expanded distally (antero-posterior diameter, 38 mm.). The prezygapophysial facets are destroyed and the concave postzygapophysial facets are unusually large.

The sixth dorsal is represented by the centrum, a damaged right diapophysis and the basal portion of the right pedicle of the neural arch. The length of the centrum is 51 mm. The diapophysis is quite broad and is compressed dorso-ventrally. Its distal facet is shallowly concave from end to end and is pitted and depressed near the center.

The right diapophysis of the seventh dorsal projects 53 mm. beyond the level of the external face of the pedicle of the neural arch. It is compressed dorso-ventrally and very little expanded distally, the antero-posterior diameter at the extremity being 42.5 mm. and the corresponding minimum medial diameter is 39 mm. The facet for the tuberculum is strongly concave from end to end and slopes obliquely downward and inward. The centrum of this dorsal is missing.

All of the processes are broken off of the centrum of the eighth dorsal. The length of the centrum is 67 mm. The incomplete right diapophysis associated with this centrum projects 51 mm. beyond the level of the external face of the pedicle of the neural arch. The distal facet does not occupy the full length of the extremity of the diapophysis, which measures 43 mm. antero-posteriorly and is flattened dorso-ventrally.

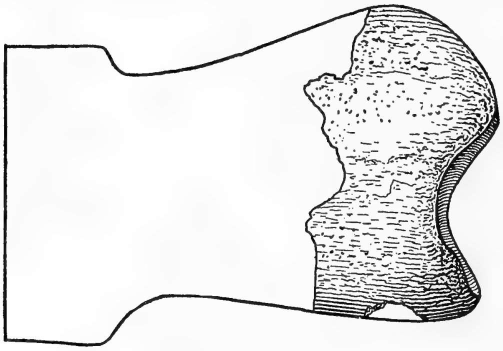


FIG. 11—Incomplete right transverse process of tenth dorsal of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Restored portion indicated by outline only. ½ nat. size.

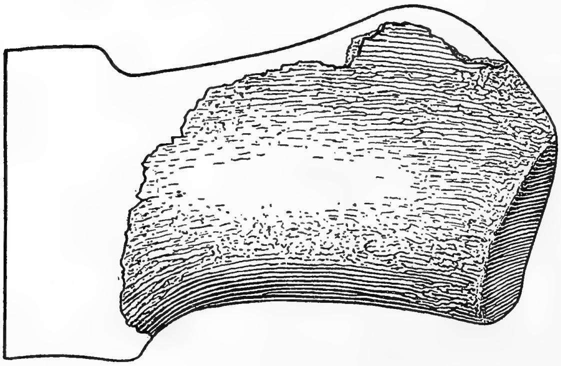


FIG. 12—Right transverse process of eleventh dorsal of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. Restored portion indicated by outline only. ½ nat. size.

The centrum alone of the ninth dorsal is preserved. Its antero-posterior diameter is 69 mm.

The distal end of the right transverse process (fig. 11) is all that is preserved of the tenth dorsal. The antero-posterior diameter of this process distally is 79 mm. The facet for articulation with the head of the corresponding rib is limited to the hinder two-thirds of the distal end of this process and produces a deep indentation. The anterior one-third of the distal end of the transverse process is regularly curved.

The anterior border of the right transverse process (fig. 12) of the eleventh dorsal is eroded, but otherwise this process is fairly well preserved. The remainder of this dorsal is destroyed. This thin transverse process is quite broad and possesses an elongated distal facet for articulation with the corresponding rib. The rounded antero-distal angle of this process is quite similar to that of the tenth dorsal, the hinder edge is nearly straight and the distal facet is shallowly concave.

A portion of the centrum and a complete right transverse process (fig. 13) are all that remain of the twelfth dorsal. The transverse process projects outward approximately 128 mm. and measures 93.5 mm. antero-posteriorly at its distal end and 63.2 mm. antero-posteriorly near the base. It is slightly larger than the corresponding process of the eleventh dorsal and, with the exception of the restriction of the concave distal facet for articulation with head of twelfth rib to the hinder one-half of its distal end, is quite similar in appearance.

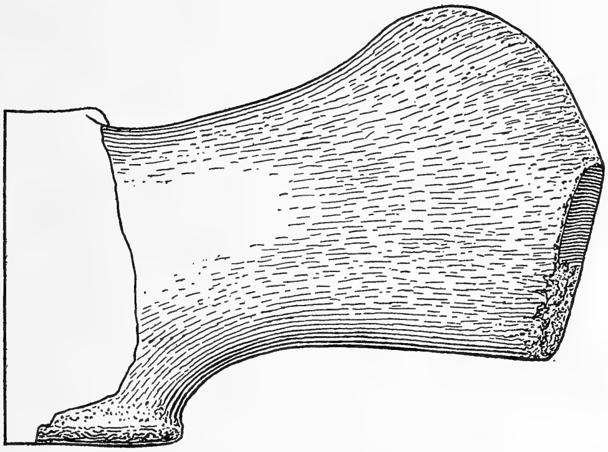


FIG. 13—Right transverse process of twelfth dorsal of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

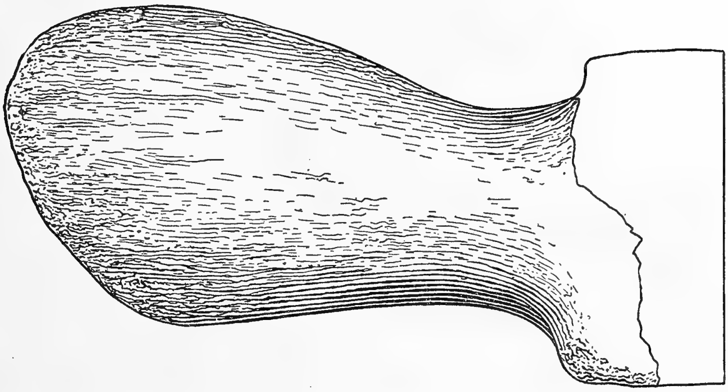


FIG. 14—Left transverse process of second lumbar of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

LUMBAR VERTEBRÆ

Three anterior lumbars and a consecutive series consisting of the ninth to twelfth lumbars, inclusive, were found. These vertebræ, like those from other parts of the column, are very fragile and tend to disintegrate very rapidly when exposed in the matrix. When first exposed in the rather friable matrix, they were found to have a very thin external shell, but the interior was reduced to the consistency of a dry powder.

A complete left transverse process (fig. 14) and a portion of the centrum of an anterior lumbar, which is tentatively identified as the second in the series, is included among the vertebræ identified as lumbars. Although this vertebra is incomplete, it is obvious that the transverse processes are much narrower and longer than those of the hindermost dorsals. The dorso-ventrally flattened transverse process is characterized by a basal constriction and a distal expansion. The anterior edge displays a pronounced convex curvature from base to antero-distal angle, and the hinder edge is nearly straight. Behind the rounded antero-distal angle, the distal end is truncated obliquely. The measurements of the left transverse process are as follows: Maximum length, 148 mm.; maximum antero-posterior diameter near distal end, 84 mm.; and minimum antero-posterior diameter near base, 52.8 mm.

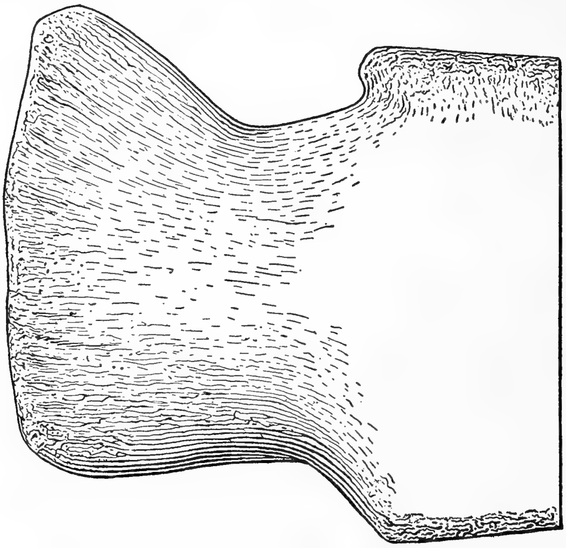


FIG. 15—Left transverse process of eleventh lumbar of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

On the third lumbar, both transverse processes are destroyed, the neural arch is crushed, and the neural spine is missing. The length of this centrum is 85 mm. and the vertical diameter of its anterior face is 66 mm. The neural canal seems to have been wider than high. The laterally flattened metapophysis is elongated, projecting upward and forward, and is extended forward considerably beyond the level of the anterior end of the centrum. The anterior edge of the basal portion of the pedicle of the neural arch is nearer the anterior face of the centrum than its hinder edge is to the posterior face. The least antero-posterior diameter of the right pedicle is 54 mm.

The fourth lumbar lacks the neural spine, the right transverse process is missing and the distal end of the left transverse process is destroyed. The curvature of the anterior and posterior margins of the transverse process indicate that its distal end was slightly expanded antero-posteriorly. The neural canal is somewhat crushed and distorted, but anteriorly measures 31 mm. transversely and 24 mm. vertically. The least antero-posterior diameter of the left pedicle of the neural arch is 56 mm. The anterior edge of the basal portion of this pedicle is nearer the anterior face of the centrum than its hinder edge is to the posterior face. The metapophyses are elongated, flattened from side to side and project upward and forward. The prezygapophysial facets are narrow, concave from side to side and project forward at least 36 mm. beyond the level of the anterior face of the centrum. A prominent longitudinal carina is present on the ventral surface of the centrum. The measurements of this vertebræ are as follows: Length of centrum, 87 mm.; vertical diameter of centrum anteriorly, 61 mm.; vertical diameter of centrum posteriorly, 63 mm.; posterior margin of left pedicle of neural arch to tip of metapophysis, 99 mm.; and least antero-posterior diameter of transverse process near base, 57 mm.

The eroded centrum of the fifth lumbar was found. It measures 92.5 mm. in length.

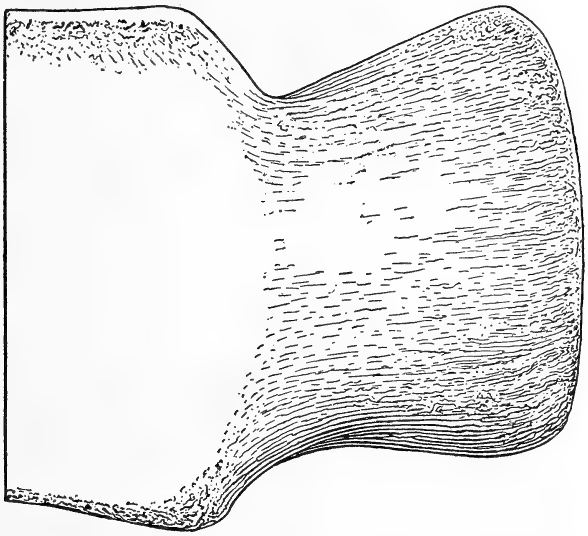


Fig. 16—Right transverse process of twelfth lumbar of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

The centrum of the ninth lumbar is eroded, and the neural arch, metapophyses and neural spine are destroyed. The basal portions of the transverse processes, however, are preserved. These processes are relatively wide antero-posteriorly. A prominent longitudinal carina is present on the ventral face of the centrum. The length of the centrum is 112 mm.

The tenth lumbar is likewise incomplete. The length of the centrum is 117 mm. and the transverse diameter of its posterior face is 100 mm.

On the eleventh lumbar, the neural arch, metapophyses and neural spine are destroyed. The broad transverse process (fig. 15), which is complete, expands abruptly beyond the basal third of its length, forming an acute antero-distal angle. The minimum antero-posterior diameter (86 mm.) of this process near the base is greater than its maximum length (80 mm.), and the maximum antero-posterior diameter of its distal end is 118 mm. A longitudinal carina is present on the ventral face of the centrum. The length of the centrum is 127 mm. and the transverse diameter of its anterior face is 88 mm., which is considerably less than the corresponding measurement of the hinder face.

On the twelfth lumbar, the broad transverse processes (fig. 16) are less noticeably contracted antero-posteriorly near the base. Otherwise, this lumbar is quite similar to the preceding one. The measurements of this vertebra are as follows: Length of centrum, 127 mm.; transverse diameter of centrum posteriorly, 112 mm.; vertical diameter of centrum posteriorly, 91 mm.; transverse distance between distal ends of transverse processes, 290 mm.; length of right transverse process, 91 mm.; maximum antero-posterior diameter of transverse process near extremity, 116.5 mm.; minimum antero-posterior diameter of transverse process, 95 mm.

Caudal Vertebræ

A consecutive series of five anterior caudals were found in place behind the hindermost lumbars. The centra of these caudals decrease in length from the first to the fifth, the neural canals rapidly decrease in size and the same is true of the lengths of the neural spines.

The first caudal has a rather high and quite narrow neural canal, a very broad neural spine, the antero-posterior diameter at the base being 98 mm., and the lateral surface of the centrum is slightly depressed above the transverse processes. The measurements of this caudal are as follows: Maximum vertical diameter, ventral face of centrum to tip of neural spine, 295 mm.; length of centrum, 135 mm.; vertical diameter of centrum anteriorly, 96 mm.; transverse diameter of centrum anteriorly, 97 mm.; vertical height of neural canal anteriorly, 45 mm.; transverse diameter of neural canal anteriorly, 19 mm.; transverse distance between distal ends of transverse processes, 280 mm.; and length of right transverse process, 112 mm.

On the second caudal, the neural spine is very broad, measuring at its rounded distal end at least 67 mm. antero-posteriorly. The neural spine rakes backward, the slope of the anterior edge being at least 45 degrees, but the upward and backward slope of the hinder edge is not so pronounced. The neural canal is not as high (30 mm.) as that of the first caudal and is also narrower transversely (11 mm.). The lateral surface of the centrum above the transverse process is concave from end to end. The broad transverse processes are not perforated at the base by a foramen, and the antero-basal angle is nearer to the anterior face of the centrum than the postero-basal angle is to the hinder face. On the ventral surface of the centrum the posterior hæmapophyses are well developed and are separated by a longitudinal groove. The measurements of this caudal are as follows: Maximum vertical diameter, ventral face of centrum to tip of neural spine, 118 mm.; length of centrum, 131 mm.; vertical diameter of centrum posteriorly, 91 mm.; antero-posterior diameter of neural spine above base, 83 mm.; and vertical diameter of neural spine, roof of neural canal to distal end, 101 mm.

The third caudal is complete with the exception of the distal end of the neural spine. The lateral face of the centrum is crossed obliquely by a rather broad groove, which extends forward from the hinder end of the centrum to the foramen which pierces the base of the transverse process. An obliquely placed osseous ridge forms the superior boundary of this groove. The fore and hinder edges of the transverse process at the base are rather close to the corresponding ends of the centrum. The neural canal is relatively low and narrow, and the laterally flattened metapophyses are not elevated more than 27 mm. above the dorsal face of the centrum. The neural spine is somewhat shorter than that of the preceding caudal and is also narrower antero-posteriorly. This spine rakes backward and is somewhat narrowed toward the apex. The measurements of this caudal are as follows: Length of centrum, 132 mm.; transverse diameter of centrum anteriorly, 93.5 mm.; vertical diameter of centrum anteriorly, 93 mm.; transverse distance between distal ends of transverse processes, 168± mm.; antero-posterior diameter of neural spine above base, 67 mm.; and vertical diameter of neural spine, roof of neural canal to distal end, 80 mm.

The centrum of the fourth caudal (length 130 mm.) is slightly shorter than that of the third caudal. The relatively short transverse processes, which are pierced at the base by a foramen, extend almost the full length of the centrum. Each of these processes is truncated obliquely from the antero-external angle to the postero-basal angle.

On the fifth caudal, an anterior and a posterior remnant of the transverse process, which are separated by a shallow vertical groove, persist. The centrum is considerably shorter than that of the fourth caudal. The anterior face of the centrum is almost hexagonal in outline and the neural canal is quite small and very low. The anterior hæmapophyses are rather large, at least 20 mm. wide, and are separated by a median longitudinal groove. The measurements of this caudal are as follows: Length of centrum, 113 mm.; vertical diameter of centrum anteriorly, 90 mm.; and transverse diameter of centrum anteriorly, 100 mm.

Fore Limb

The shoulder blade is represented by portions of both scapulæ, which are in part complementary, permitting a fairly accurate restoration of that element. The left humerus, the proximal third of the left ulna and the major portion of the shaft of the right ulna, furnish the proportions of the limb bones. Four carpals, six metacarpals and eighteen phalanges, some from the right side and others from the left, show the main features of the hand.

Scapula

The right scapula is represented by a large fragment comprising the posterior angle and the vertebral margin. Six fragments of the left scapula furnish the general contours of the remainder of the scapula. A reconstruction of the scapula (fig. 17), lacking only in the original outline of the acromion, the coracoid process and the articular head is thus possible.

The anterior portion of the left scapula consists of six fragments, four of which join together, giving the true width of the basal portion of the blade. A portion of the acromion, which crumbled while being prepared, was recorded as occupying the approximate position shown on the reconstruction (fig. 17). The piece forming the anterior angle shows the curvature of the anterior margin and a considerable part of the vertebral margin. The position of this fragment in the reconstructed scapula is determined within a small probable error by alignment with an adjacent piece forming the lower anterior edge. The posterior angle and the hinder half of the vertebral margin are known from a piece of the right scapula.

Unfortunately, the exact position of this fragment in the reconstruction had to be determined by a study of the relative thickness of the adjacent parts, on the assumption that the scapula in that region was of uniform thickness, and by alignment with the posterior margin of the left scapula.

The articular head of the scapula, including the glenoid fossa, has been reconstructed to conform to the known margins and also to the shape and size of the head of the humerus. The coracoid process has been drawn in accordance with the form and size of the same process in some allied Miocene cetotheres.

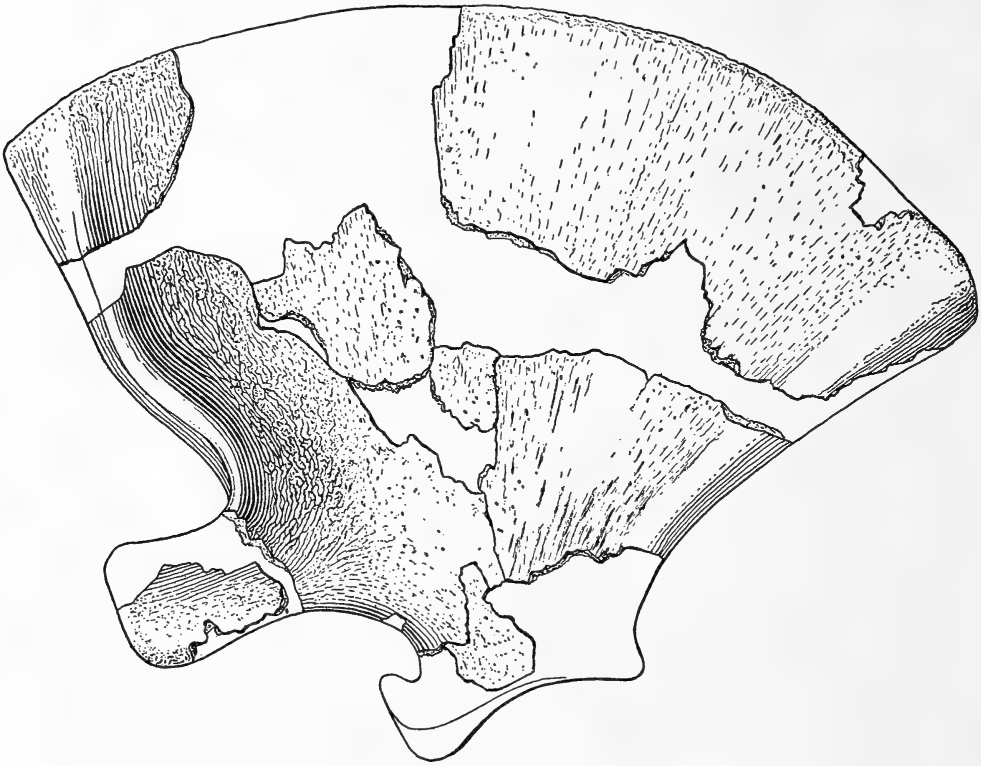


Fig. 17—Reconstructed left scapula of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. ⅓ nat. size.

The scapula as reconstructed is relatively narrow and high, the ratio of height to maximum width being approximately 7 to 10. The anterior edge is curved convexly between the anterior angle and the base of the acromion. The anterior angle of the scapula is about 10 mm. thick and its vertebral margin is rugose. The anterior border becomes thicker toward the lower end and turns inward above the acromion, where it apparently terminates on the costal face of that process. The low rounded spinous crest parallels and overhangs the narrow anterior border of the scapula. Below the anterior angle, this crest curves forward, and ventrally it is continuous with the upper edge of the acromion. The area between the anterior edge and the spinous crest of the scapula, corresponding to the supraspinous fossa of less specialized scapulæ, is narrow, shallow and flattens out dorsally. The lower portion of the posterior margin of the left scapula is somewhat curved but, as reconstructed, tends to become more nearly straight toward the posterior angle. The lower hinder fragment presents a thick rounded margin. Toward the middle the scapula is quite thin, in places not exceeding 6 mm. in thickness. The vertebral margin at the posterior angle is not more than 9 mm. in thickness and is distinctly rugose, which suggests the presence of some sort of a cartilaginous extension along the entire vertebral margin. No distinct areas for the attachment of the several muscles are indicated on the lateral surface of the scapula. The costal surface of the scapula is relatively flat, smooth and devoid of conspicuous ridges.

Measurements of reconstructed scapula (in millimeters)

Maximum antero-posterior diameter, measured in a straight line from angle to angle	380
Maximum transverse diameter, measured parallel to tangent of glenoid fossa as reconstructed	300
Maximum vertical diameter as reconstructed	270
Length of acromion	69±
Average thickness of vertebral margin	4

HUMERUS

The left humerus (fig. 18) is short and robust, with a rounded head and an enlarged distal end. The convex articular surface of the head is elliptical in outline, having a maximum diameter of 87 mm. The head

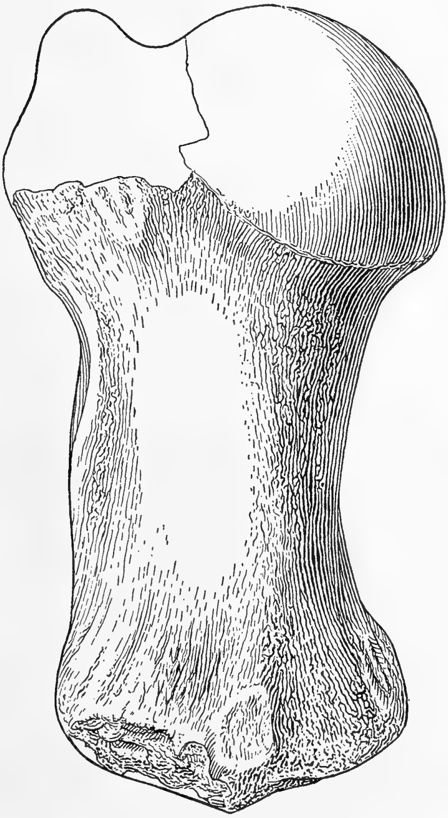


FIG. 18—Left humerus of *Cophocetus oregonensis*, No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

is placed obliquely on the shaft, facing outward and backward. The articular surface of the head is relatively smooth except along the outer lower border where it is rugose. Both epiphyses are fused with the shaft. Unfortunately, the tuberosity is imperfectly preserved, but the presence of a large basal enlargement indicates a strongly developed process. The shaft decreases in size from the level of the lower margin of the head to a point beyond the level of the middle of its length and then widens to form the expanded distal extremity.

The anterior or radial face of the shaft is quite thin and is modified to form a rugose curved crest which extends from below the tuberosity to the antero-distal angle of the shaft. The hinder face of the shaft is quite broad and somewhat convex. On the distal end of the shaft the ulnar articular surface is slightly larger than the radial facet and these two facets are separated by a low transverse crest. The ulnar facet is somewhat saddle-shaped and extends upward on the hinder face of the distal end of the shaft. It is smooth and slightly concave from side to side and meets the radial facet at an angle of approximately 25 degrees. The radial facet is imperfectly preserved.

Measurements of left humerus (in millimeters)

Maximum length of humerus	206
Minimum antero-posterior diameter of shaft near middle	70
Maximum diameter of articular head	87
Maximum diameter of proximal end	110±
Maximum antero-posterior diameter of distal end	90
Maximum transverse diameter of distal end	46.5
Antero-posterior diameter of ulnar articular surface	57

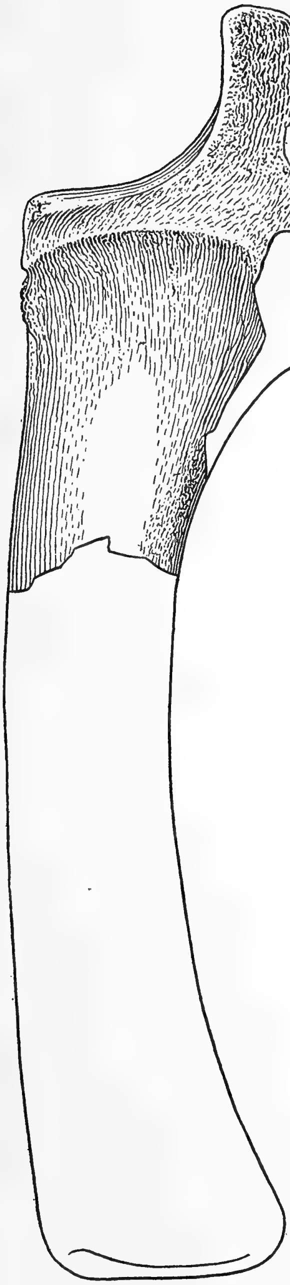
Radius

No fragments of either radius were found.

Ulna

The left ulna (fig. 19) is represented by a proximal fragment, including the greater part of the olecranon process, which measures 158 mm. in length. The relatively slender upper portion of the shaft is oval in cross-section. The proximal end is expanded to form the olecranon process. The greater sigmoid cavity is curved from end to end, forming about one quadrant of a circle having a diameter of nearly 80 mm. The articular surface of the greater sigmoid cavity for the trochlea of the humerus is not more than 12 mm. wide near its upper limit, but at least 35 mm. wide near its lower anterior border. The dorsal angle of the olecranon process is bluntly pointed and the dorsal margin is abruptly curved downward and backward. The hinder portion of this process has been destroyed. Below the lower anterior margin of the greater sigmoid cavity is a very rugose and rather large area for articulation with the radius. The vertical diameter of this rugose area is at least 35 mm. The external portion of this area probably corresponds to the position of the attachment of the extensor muscles of the digits.

The distal end of the right ulna (fig. 20) is crushed transversely and the proximal end is incomplete. The shaft is elongated, expanded at both ends and noticeably curved. The hinder profile of the shaft viewed from the side is more strongly curved than the anterior profile, and the curva-



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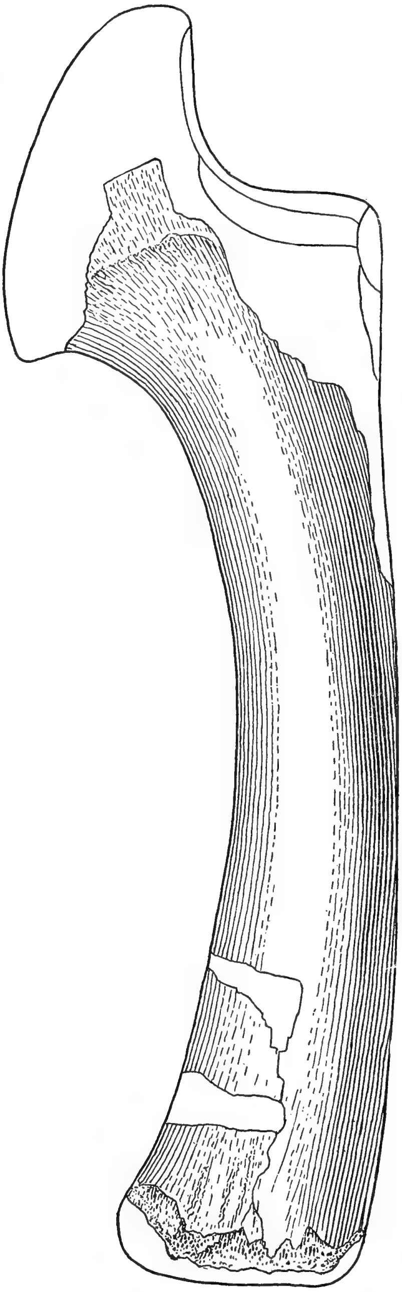

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FIG. 19—External view of proximal end of left ulna of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Restored portion indicated by outline only. ½ nat. size.

FIG. 20—External view of right ulna of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. Restored portion indicated by outline only. ½ nat. size.

ture is especially pronounced at the upper end where it merges with the olecranon process. A thin crest-like anterior edge and a rounded hinder edge further characterize the transversely flattened shaft. The distal end, though crushed, retains much of its original appearance, and the postero-distal angle is projected backward.

Measurements of the left ulna (in millimeters)

Maximum length of ulna, estimated	325±
Distance from dorsal to ventral end of greater sigmoid cavity	67
Minimum antero-posterior diameter of shaft below greater sigmoid cavity	42.5
Minimum transverse diameter of shaft below greater sigmoid cavity	24

Measurements of the right ulna (in millimeters)

Maximum length, as preserved	290
Maximum antero-posterior diameter of distal end	61
Minimum antero-posterior diameter near middle of shaft	43
Minimum transverse diameter near middle of shaft	20
Maximum transverse diameter of proximal end of shaft	32

Carpals

The number of mesopodials originally present in the carpus of this cetothere is unknown and although those that were found are completely ossified, their homologies are uncertain. The one undamaged carpal is a small irregularly elliptical bone with very rugose articular faces which unquestionably were covered with cartilage. The measurements of this carpal are as follows: Maximum transverse diameter, 36 mm.; maximum vertical diameter, 24.5 mm.; and maximum dorso-plantar diameter, 20.5 mm. This carpal element (? trapezoid) lay in the matrix betweeen the distal end of the right ulna and the head of the second metacarpal. Another large carpal (? magnum), which partially disintegrated during preparation, was found between the postero-distal end of the right ulna and the head of the third metacarpal. A third carpal element (? trapezium), somewhat smaller than either of the preceding, was removed from the matrix above the head of the first metacarpal. The fourth carpal element (? cuneiform) is sub-quadrangular in outline. All four of these metacarpals have relatively smooth dorsal and plantar faces and the remaining surfaces are strongly rugose. The marked roughening of the articular faces of these carpals indicates that the carpus had become extensively cartilaginous. Several pieces of partially disintegrated bones, which may possibly represent carpals, were also found near the distal end of the right ulna. Fortunately, the four carpals described above were photographed before they were entirely freed from the matrix and their outlines are used in the reconstructed manus.

Metacarpals and Phalanges

The digits are represented by 24 bones, a number of which were found in the relative positions shown on the reconstructed manus (fig. 21). Eight bones were found in close proximity to the right ulna, and of these the three metacarpals (I, II, III) were preserved apparently in their natural sequence. Behind the third metacarpal is a phalanx which is determined as the first or proximal joint in the fourth digit. Below the second metacarpal was found a smaller phalanx which no doubt is the first or

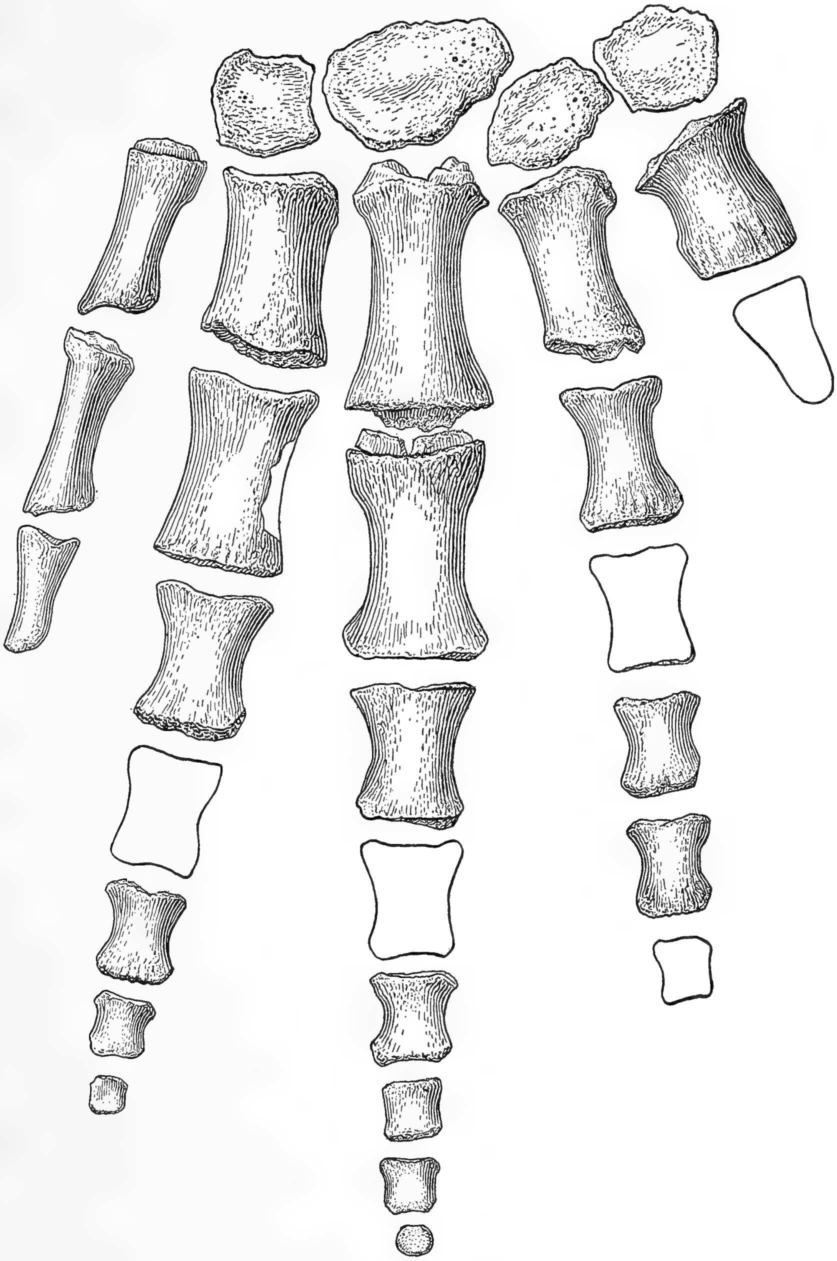

FIG. 21—Reconstructed right manus of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. The carpals as well as digits I and II are based on the corresponding elements in the left manus and are drawn reversed. Dights III, IV and V belong to the right manus. Restored elements indicated by outline only. ½ nat. size.

proximal joint of the second digit. Two smaller phalanges were found in close proximity to the second metacarpal and presumably belong to the second digit. The basal portion of the distal phalanx of the fifth digit was also found.

Sixteen finger bones belonging to the left manus were present in one block of matrix. Metacarpals IV and V were found lying side by side, and metacarpal III lay nearby. Although the thirteen phalanges associated with these three metacarpals did not lie in natural sequence, the positions in which they were found suggested the restoration shown in figure 21. Inasmuch as two of the six metacarpals, which were found, represent the same elements in opposite flippers, and since the four remaining metacarpals are quite dissimilar in appearance, there is reason to believe that five digits were present in each manus.

All of the metacarpals are conspicuously flattened in a dorso-plantar direction except the fifth, which is convex above and flattened on the plantar side. The shaft of the slender fifth metacarpal is slightly contracted medially and on its head is an osseous excrescence which may have been enveloped by cartilage. The concave distal end of the shaft is obliquely truncated.

Metacarpal IV is relatively short, broad, conspicuously flattened in a dorso-plantar direction and very slightly contracted medially. The head or proximal end of this metacarpal is somewhat rugose, its antero-proximal angle is conspicuously flattened in an oblique direction and its distal end is obliquely truncated.

Measurements of the metacarpals (in millimeters)

	I.R	II.R	III.L	IV.L	V.L
Maximum length	41	51	59	51.8	46
Minimum transverse diameter of shaft	26.2	20.5	23.7	27.3	14.5
Maximum transverse diameter of proximal end	34.6	29.3	35.2	31.7	20.1
Maximum transverse diameter of distal end	30	24.3	38.5	33.8	18

The third metacarpal is considerably larger and longer than the others. As regards length and general appearance, the right and left metacarpal III are quite similar, but the distal end of the left one is less expanded. The proximal end of this metacarpal is expanded transversely and osseous excrescences are present on both ends. The postero-proximal angle of the head is flattened laterally, suggesting limited contact with the corresponding angle of metacarpal IV. No indication of possible contact with the corresponding angle of metacarpal II is present on the antero-proximal angle of the head of metacarpal III. The shaft is abruptly contracted below the head and then gradually increases in width to the transversely expanded distal end. Although the right and left metacarpal III are slightly crushed, the plantar face apparently is more flattened than the dorsal face.

The second metacarpal of the left manus has a much narrower shaft than either the first or the third metacarpal. Its antero-proximal angle is produced laterally, the surface being distinctly rugose. The presence of this lateral extension is difficult to interpret in view of the shape of the corresponding angle of the first metacarpal. There might be some question as to the position of this metacarpal, were it not for the fact that metacarpals I, II and III of the left manus were found in what appears to be their natural sequence. The rugose proximal end of metacarpal II is truncated at almost right angles to the shaft, but the distal end is obliquely truncated.

The first metacarpal is short, broad and conspicuously flattened in a dorso-plantar direction. The somewhat concave proximal face is quite rugose. The shaft below the transversely expanded head preserves a nearly uniform width to its distal end.

The phalangeal formula of the manus of this cetothere seems to have been:

Metacarpals	I	II	III	IV	V
Phalanges	1	5	7	6	2

Five of the eighteen phalanges associated with this skeleton belong to the right manus and thirteen to the left manus; two of those belonging to the right manus are obviously duplicated among those found with the phalanges of the opposite manus. The relative positions of at least eight of the thirteen phalanges belonging to the left manus are definitely known, and these belong to the third and fourth digits.

The first digit may have had at least one phalanx, but this is missing. Four phalanges, decreasing in size from the proximal to the distal one, presumably belong in the second digit of the right manus. The second phalanx is supposedly missing.

As reconstructed, the third digit is the longest of the five digits. The elongation of the third digit is likewise characteristic of *Eubalæna glacialis* and *Balæna mysticetus*. If one may rely on the decreasing dimensions of the six phalanges which are allocated to this digit, then it is obvious that the third phalanx is missing. The third digit thus may have had at least seven phalanges.

The sequence of the phalanges in the fourth digit is undoubtedly approximately correct since the penultimate phalanx was found in the position shown in the reconstructed manus (fig. 21). The first or proximal phalanx lay between metacarpal IV and the second phalanx, but the fourth phalanx was separated by a greater interval from the second phalanx. The measurements of these phalanges indicate that the third phalanx is missing. The phalanges of the fourth digit form a well-graded series, becoming progressively shorter, flatter and terminating in small quadrangular bone scarcely recognizable as a phalanx.

Measurements of the phalanges (in millimeters)

	1	2	3	4	5	6	7
Digit II—							
Greatest length	37.5		26	25			
Minimum transverse diameter of shaft	17.5		16	14.8			
Minimum thickness of shaft	5.6		5	5.2			
Maximum diameter of proximal end	26.8		22.3	21.2			
Digit III—							
Greatest length	55.5	48		25.5	16.5	14.3	8
Minimum transverse diameter of shaft	25	21		16.2	13.8	12	9.2
Minimum thickness of shaft	9	7		6.5	5	4	2.5
Maximum diameter of proximal end	36.2	27.4		20.8	15.4	14.8	
Digit IV—							
Greatest length	49	38		25	17	10	
Minimum transverse diameter of shaft	24	20.8		14.3	12.2	9	
Minimum thickness of shaft	7.7	6.7		4.5	5.2	2.8	
Maximum diameter of proximal end	34.8	30		21	15.3	10.3	
Digit V—							
Greatest length	51	31.8					
Minimum transverse diameter of shaft	11.5	8.8					
Minimum thickness of shaft	8.4	4.8					
Maximum diameter of proximal end	20	15.5					

Two slender and elongated phalanges, which do not fit naturally into the sequence of the phalanges of the four previously described digits, are allocated to the fifth digit.

The phalanges of all the digits, with the exception of the fifth, are conspicuously widened and also flattened in a dorso-plantar direction.

PELVIS

It is particularly fortunate that both innominate bones of this cetothere are preserved. They are proportionately longer than those of living balænopterine whales, if the estimated length of 4.6 meters for the Newport skeleton is approximately correct. No marked asymmetry exists between the right (fig. 22) and left (fig. 24) innominate bones. The conspicuous side to side compression of the short, broad pubic portion of the Newport innominate bone, as well as the rather delicate construction of the bone as a whole, are peculiarities which have not been observed in the pelvic elements of recent mysticetes. Although the pelvic elements of the recent finback[1] exhibit considerable variation in the conformation of their com-

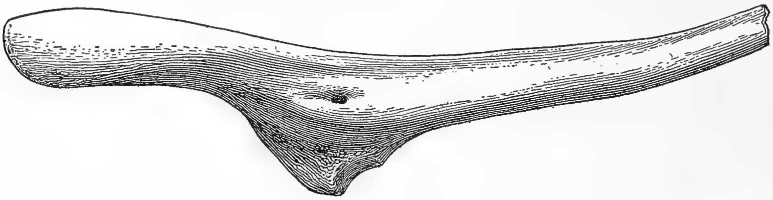

FIG. 22—External view of right innominate bone of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

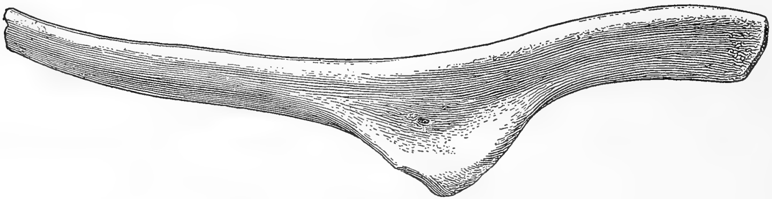

FIG. 23—Internal view of right innominate bone of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

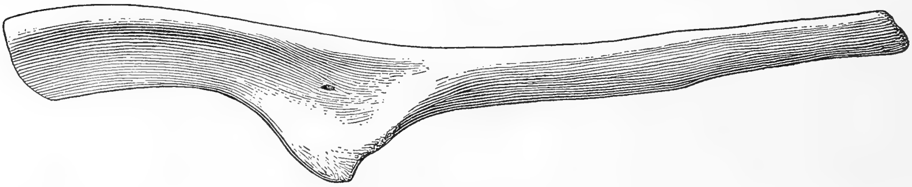

FIG. 24—Internal view of left innominate bone of *Cophocetus oregonensis,* No. 305, Condon Mus., Univ. Oregon. ½ nat. size.

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[1] W. Augustin, *Die Formvariabilität der Beckenknochen bei nord-atlantischen Bartenwalen,* Zool. Jahrb., Abt. f. Syst., Jena, vol. 35, pl. 19, 1913.

ponent parts, in no instance was there any approach among those examined to the pronounced flattening of the pubis which characterizes the innominate bones of the Newport cetothere. It seems rather curious that the retrogressive remodeling of these pelvic elements, in comparison with those of recent Mysticeti, had reached such an advanced stage in a Miocene cetothere.

Each of these fossil innominate bones exhibits a somewhat sinuous curvature from end to end. The outer or lateral surface of the ilium is flattened and the internal or medial surface is slightly convex. The elongated iliac process is somewhat prismatic near the base, being more or less flattened on its external and dorsal faces, and convex internally. The ilium is strongly compressed from side to side toward its attenuated anterior end, where the maximum thickness does not exceed 2 mm. As compared with the left innominate bone of *Balænoptera physalus* figured by Abel,[1] the corresponding element of this cetothere is shorter, the iliac process is similarly elongated, the diameter of the bone through the pubis is considerably less and the ischial process is more flattened. On both the right and left innominate bones of this cetothere, the ilium is conspicuously longer than the ischium, even though the anterior portion of the right iliac process is destroyed. The elongation of the iliac portion seems to be a characteristic peculiarity of the innominate bone of most mysticetes.

Measurements of the innominate bones (in millimeters)

	Right	Left
Maximum length	194+	231
Maximum vertical diameter through pubis	36.2	37
Minimum vertical diameter of ischium	17	18.2
Transverse diameter of ischium at same level	9	8.2
Distance from apex of pubic process to postero-ventral angle of ischium	94	97
Distance from apex of pubic process to anterior end of ilium	118+	147.5

The pubis is reduced to a short, bluntly pointed process which is curved downward and inward at its apex and also along its hinder border. Between its apex and the ischium, the hinder border of the pubic process is quite thin and its outer surface is slightly roughened. A saddle-shaped depression on the rather broad antero-external edge and below the apex of the pubis may correspond to the acetabulum. This is especially interesting since the innominate bones of *Balænoptera physalus* figured by Abel possess a vestigial socket on the outer and hinder surface of the pubis. The blunt end of the pubic process of *Sibbaldus musculus* is covered with a cartilaginous cap, which corresponds with the acetabular cartilage according to Struthers.[2] The vestigial femur did not articulate with this acetabular cartilage, but lay in the angle between the pubis and the ilium. As described by Struthers,[3] the ligament of the femur is attached to the ridge which extends across the hinder part of the under

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[1] O. Abel, *Die Morphologie der Hüftbeinrudimente der Cetaceen,* Denkschr. k. Akad. Wiss, math.-naturw. Kl., Wien, vol. 81, 150, figs. 11, 12, 1907.

[2] J. Struthers, *On the rudimentary hind-limb of a great fin-whale (Balænoptera musculus) in comparison with those of the humpback whale and the Greenland right-whale,* Jour. Anat. & Physiol., London, vol. 27, pt. 3, 295, pl. 19, figs. 4-5; pl. 20, fig. 8, Apr. 1893.

[3] J. Struthers, *On some points in the anatomy of a great fin-whale (Balænoptera musculus),* Jour. Anat. & Physiol., London, vol. 6, 109-110, Nov. 1871.

surface of the pubic process. This ridge is not developed on the innominate bones of the Newport cetothere, but the corresponding area is somewhat roughened.

Near the fore part of the base of the pubic process of *Balænoptera physalus,* a foramen is frequently present. This may correspond to the minute foremen in the Newport innominate bone, which is located, however, much nearer to the dorsal margin of this element and above the pubic process. It is of some interest that the innominate bone of the recent *Rhachianectes glaucus* is pierced transversely by a foramen in the same relative position as this fossil bone.

The laterally flattened ischium is shorter than the ilium and displays a rounded hinder extremity. The hinder end of the right ischium is complete, but it was necessary to restore the partially disintegrated hinder end of the left ischium.

Although careful search was made, no remnants of either femur were found.

REMARKS

As compared with *Tiphyocetus temblorensis,*[1] the Newport cetothere has smaller occipital condyles, but the distance between the upper margin of the foramen magnum and the rather narrow apex of the supraoccipital shield as well as its transverse diameter above the occipital condyles are approximately the same, the vertical diameter of the braincase is less, the distance between the hinder ends of the nasals and the apex of the supraoccipital shield is shorter, the lateral protuberances on the basioccipital are larger, the pterygoid fossæ are smaller, and the notches for the jugular leash have a different conformation, but the zygomatic width and the distance between the outer margins of the exoccipitals are approximately the same. The periotic bones of these two cetotheres are quite dissimilar in appearance.

Peripolocetus vexillifer[2] has a much larger skull and the ventral surface of the squamosal between the level of the tympanic bulla and the postglenoid process is very strongly convex in contrast to the concave curvature of the corresponding surface on the Newport cetothere skull. This in turn indicates some modification of the usual type of articulation between the condyle of the mandible and the skull of this cetothere. The periotic bones of these two cetotheres are likewise quite different in general appearance, the periotic of the Temblor cetothere having a large swollen anterior process which is bent inward almost at right angles to the body.

The periotic bone of *Parietobalæna ? securis*[3] is so radically unlike that of the Newport cetothere that no comparisons are required.

It is particularly unfortunate that the supraoccipital shield of *Cetotherium furlongi*[4] is entirely destroyed. On the other hand, the left supraorbital process is complete on this skull, but both of these processes

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[1] R. Kellogg, *Pelagic mammals from the Temblor formation of the Kern River region, California,* Proc. Calif. Acad. Sci. (4), vol. 19, No. 12, 317-332, figs. 74-81, 1931.

[2] R. Kellogg, *op. cit.,* 338-343, figs. 89-91, 1931.

[3] R. Kellogg, 1931, *op. cit.,* 343-348, figs. 92-93.

[4] R. Kellogg, 1925, *Fossil cetotheres from California,* Contrib. Palæont., Carnegie Inst. Wash. Pub. No. 348, 35-50, figs. 1-6, Apr. 22, 1925.

are incomplete on the Newport skull. Nevertheless, it is certain that the contours of the temporal fossæ are quite different in these two cetotheres. Furthermore, the backward thrust of the median rostral elements is more pronounced on the Stone Canyon skull and the rostrum is more noticeably attenuated distally. The dimensions of these two cetotheres are quite similar.

The other described cetotheres from California formations are sufficiently distinct from the Newport skull to eliminate them from further consideration. The assemblage of fossil cetaceans, which characterizes the Lower Miocene Patagonian marine formation on the coast of Chubut Territory, Argentine Republic, includes at least two distinct types of cetotheres. Although the skulls of these South American cetotheres are constructed along the same general mechanical lines as those found in the Miocene formations of the Pacific Coast of North America, they exhibit obvious structural differences not only in the contours of their component parts, but also in the extent of the interdigitation of the cranial and rostral portions.

Aside from its smaller dimensions, the skull of the Newport cetothere differs from that of the Patagonian *Aglaocetus moreni* (Lydekker)[1] in having a relatively broad rostrum which is not strongly attenuated from base to distal end, a supraoccipital shield less conspicuously attenuated toward the apex, the zygomatic processes directed forward and not bent outward, larger lateral protuberances on basioccipital and temporal fossæ which are strongly narrowed internally. The condyle of the mandible also is broad and not laterally compressed.

From the Patagonian *"Plesiocetus" dyticus* Cabrera,[2] the Newport cetothere is readily distinguished by the contours of the supraoccipital shield and the squamosal portions of the skull. Furthermore, the basal portions of the supraorbital processes of the Newport skull are sufficiently complete to show that the curvature of the hinder margins of these processes is quite different from that of this Patagonian cetothere.

The Newport skull is distinguishable from the hinder cranial fragment of the Aquitanian *Cetotheriopsis lintianus* (von Meyer) [3] by the conspicuous outward prolongation of the squamosal portions of the skull and by the shape of the supraoccipital shield.

Referred Cranium

The incomplete braincase found by Mr. J. C. Snyder in a fine-grained hard calcareous concretion on the beach near Otter Rock, Oregon (see p. 21) was derived likewise from the Miocene Astoria formation. Since the apex of the supraoccipital shield is eroded on the Newport skull, it is fortunate that it is complete on the specimen from Otter Rock. This braincase shows that the supraoccipital is strongly narrowed toward the pointed apex (pl. 3). The lambdoidal crests rise at least 25 mm. above the level of the apical portion of the supraoccipital. A short sagittal crest is developed in the intertemporal region.

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[1] R. Lydekker, *Contributions to a knowledge of the fossil vertebrates of Argentina: II. Cetacean skulls from Patagonia,* Annales del Museo de La Plata, Palaeont. Argentina, vol. 2, for 1893, art. 2, 2-4, pl. 1, Apr. 1894.

[2] A. Cabrera, *Cetáceos fósiles del Museo de La Plata,* Revista del Museo de La Plata, Buenos Aires, vol. 29, 370-372, figs. 3, 4a, 1926.

[3] J. F. Brandt, Mém. Acad. Imp. Sci. St. Pétersbourg (7), vol. 20, No. 1, 40, pl. 19, 1873.

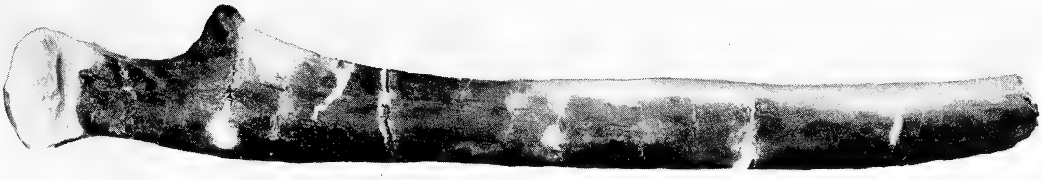
The lower portion of the supraoccipital, both occipital condyles and the right exoccipital are eroded. Both zygomatic processes, as well as the supraorbital processes of both frontals, and the entire rostrum are destroyed.

On the ventral surface of the cranium (pl. 3) one observes the same enlargement of the lateral descending processes of the basioccipital, the narrow median basicranial depression, the oblique crest on the palatine, and the large foramina ovale as characterize the Newport skull. The contours and relative proportions of the pterygoid fossa are clearly shown on this specimen.

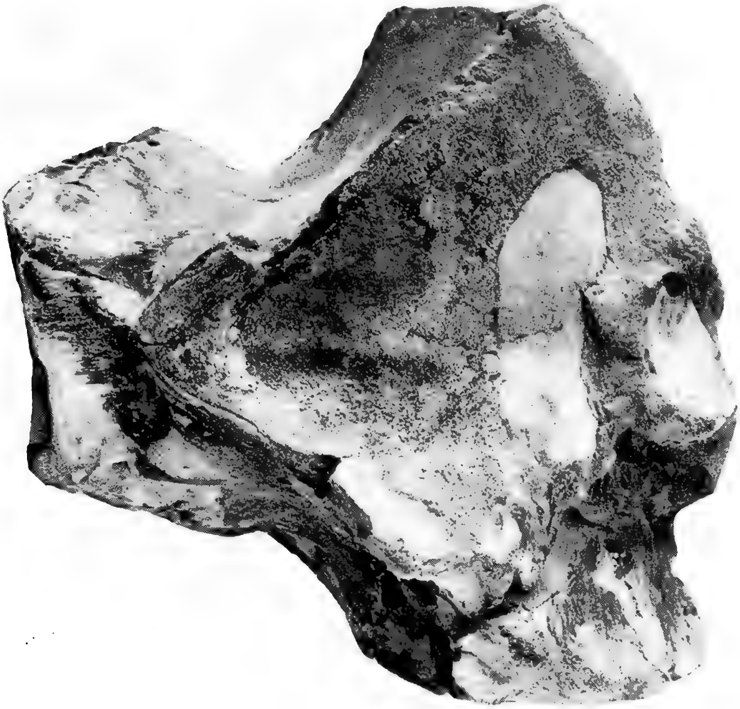
Measurements of incomplete cranium (in millimeters)

Distance from upper margin of foramen magnum to apex of supraoccipital shield	225
Least distance between inner surfaces of lateral descending processes of basioccipital	45
Greatest distance between outer surfaces of lateral descending processes of basioccipital	130
Least distance between opposite foramina ovale	181
Distance from notch between occipital condyles to hinder end of vomer	60
Maximum antero-posterior diameter of left tympanic bulla	57
Distance from end of sigmoid process to ventral face of tympanic bulla	41

Cophocetus oregonensis; No. 305, Condon Museum, Univ. Oregon; Astoria Middle Miocene, Newport, Oregon. Upper figure, dorsal view of cranium; lower figure, posterior view of cranium.



Cophocetus oregonensis; No. 305, Condon Museum, Univ. Oregon; Astoria Middle Miocene, Newport, Oregon. Upper figure, ventral view of skull; lower figure, lateral view of right mandible, with anterior end missing and condyle restored.



Cophocetus oregonensis; collection of J. C. Snyder; Astoria Middle Miocene, near Otter Rock, Oregon. Upper figure, dorsal view of cranium; lower figure, ventral view of cranium.

CONTRIBUTIONS TO PALÆONTOLOGY

II

THE PATAGONIAN FOSSIL WHALEBONE WHALE, Cetotherium moreni (Lydekker)

By Remington Kellogg

With four plates and two text-figures

[Issued January 10, 1934]

CONTENTS

THE PATAGONIAN FOSSIL WHALEBONE WHALE,

Cetotherium moreni (Lydekker)

INTRODUCTION

Since Richard Lydekker[1] published, in 1894, the description of the skull of *Cetotherium moreni,* two other examples of this cetothere have been secured, one by the La Plata Museum and the other by the Field Museum of Natural History. The type skull and vertebræ associated with it were found at "el cerro del Castillo," opposite Trelew, Province of Chubut, Patagonia. A brief description of the second skull has been published by Dr. Angel Cabrera.[2] This skull comes from the same locality and the same horizon as the type specimen.

The third skull was found on a hill southwest of Pico Salamanca, Province of Chubut, Patagonia, by members of a field party working under the direction of E. S. Riggs. Headquarters were established at the "Bay of Solano camp" of the Standard Oil Company of New Jersey and field work was carried on in the vicinity for about two months during 1923. For permission to study this specimen, the writer is indebted to Dr. O. C. Farrington and Elmer S. Riggs, Department of Geology, Field Museum of Natural History, Chicago, Illinois. The photographs were furnished by the Field Museum of Natural History and the line drawings are the work of Sydney Prentice.

DESCRIPTION OF THE CETOTHERE, Aglaocetus moreni (Lydekker)

AGLAOCETUS[3] new genus

Genotype—*Cetotherium moreni* Lydekker.

Diagnosis—Apex of supraoccipital shield thrust forward beyond level of anterior ends of zygomatic processes; nasals located in part anterior to level of preorbital angles of supraorbital processes of frontals; thin anterior process of parietal, which overrides basal portion of supraorbital process, extended forward almost to level of hinder ends of median rostral elements (ascending processes of maxillaries and premaxillaries, and the nasals); backward thrust of rostrum has carried hinder ends of median rostral elements to level of center of orbit; rostrum relatively broad at base and strongly attenuated distally; a short intertemporal constriction formed by

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[1] R. Lydekker, *Contributions to a knowledge of the fossil vertebrates of Argentina. II: Cetacean skulls from Patagonia,* Annales del Museo de la Plata, Palaeont, Argentina, vol. 2 for 1893, art. 2, pp. 2-4, pl. 1. Apr. 1894.

[2] A. Cabrera, *Cetáceos fósiles del Museo de La Plata,* Revista del Museo de La Plata, Buenos Aires, vol. 29, pp. 369-370, fig. 4 B, 1926.

[3] Ἀγλαός splendid; κῆτος, whale—in allusion to the general appearance of the skull.

parietals, with narrow sagittal crest; exposure of frontals in median interorbital region reduced to a narrow strip; zygomatic processes bent outward; alisphenoid present in temporal wall of braincase; condyle of mandible strongly compressed transversely, with furrow on internal face near ventral border.

Aglaocetus moreni (Lydekker)

Referred specimen—Cat. No. p. 13407, Department of Geology, Field Museum of Natural History, Chicago, Ill. A nearly complete skull and both mandibles.

Locality—About two miles west of the present shore line of Bahía Solano, southwest of Pico Salamanca and north of Commodoro Rivadavia, about three kilometers east northeast of the Administración of the Compañía Solano, and at an elevation of 400 to 500 feet above sea-level, Province of Chubut, Patagonia. The skull was found on a hill about 400 feet above and about half a mile east of a well which was being drilled by the Standard Oil Company of New Jersey during July 1923, in or at least near the bed of a creek (? Spring Creek). Collected by J. B. Abbott and George Sternberg, members of E. S. Riggs' party from the Field Museum of Natural History.

Horizon—The Lower Miocene Patagonian marine formation.

SKULL

This skull is characterized by a moderate forward thrust of the supraoccipital and the parietals and a limited backward thrust of the rostral elements, a relatively short and strongly pinched-in intertemporal constriction, a minimum exposure of frontals in interorbital region, temporal fossæ relatively short antero-posteriorly and wide transversely, a narrow and elongate dorsal narial fossa, slender outwardly bowed zygomatic processes, a robust postglenoid process, and by having postero-internal portions of squamosals projected backward to conceal lateral portions of exoccipitals, except for external ends, when viewed from above.

Dorsal view—From a dorsal view (fig. 1), attention is at once directed to the triangular supraoccipital shield which is strongly narrowed to its pointed apex, the strongly concave curvature of the dorsal surface of the postero-internal portions of the squamosals, the forward overthrust of the parietal on the base of the supraorbital process of the frontal, the presence of a transverse temporal crest on each supraorbital process, the relatively narrow (antero-posteriorly) supraorbital processes, the bowed outward zygomatic processes, and the rapidly attenuated rostrum. The forward thrust of the hinder cranial elements has carried the thin anterior processes of the parietals forward over the supraorbital processes of the frontals almost as far as the level of the hinder ends of the ascending processes of the maxillaries.

On the right side of the rostrum (pl. 1), the anterior half of the outer edge as well as the postero-external angle of the maxillary is destroyed. The entire outer border of the left maxillary, with the exception of the postero-external angle and that bordering the antorbital notch, is destroyed. Judging from the type skull of this species, which has been figured by Lydekker, the rostrum is characterized by its pronounced distal attenuation. The rostrum contributed about 68 per cent of the total length of the skull.

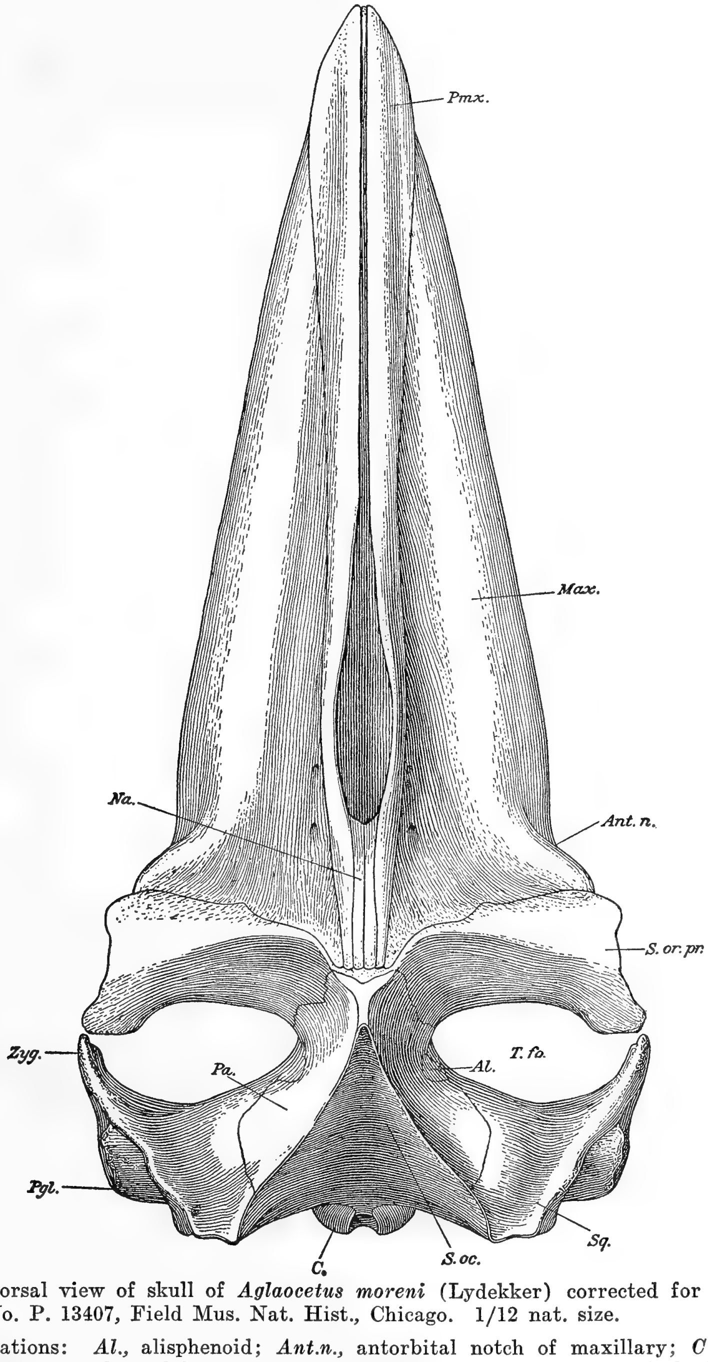

FIG. 1—Dorsal view of skull of *Aglaocetus moreni* (Lydekker) corrected for distortion, No. P. 13407, Field Mus. Nat. Hist., Chicago. 1/12 nat. size.

Abbreviations: *Al.*, alisphenoid; *Ant.n.*, antorbital notch of maxillary; *C.*, occipital condyle; *Ext. a.m.*, channel for external auditory meatus; *Ex. oc.*, exoccipital; *f. ov.*, foramen ovale; *J. n.*, notch for jugular leash; *L. pr.*, lateral process of basioccipital; *Max.*, maxillary; *Na.*, nasal; *O.c.*, optic canal; *Pa.*, parietal; *Pal.*, palatine; *Per.*, periotic; *P.gl.*, postglenoid process; *Pmx.*, premaxillary; *P.pr.*, posterior process of periotic; *Pt.*, pterygoid; *S.oc.*, supraoccipital; *S.or.pr.*, supraorbital process of frontal; *Sq.*, squamosal; *T.fo.*, temporal fossa, *Zyg.*, zygomatic process of squamosal.

The maxillaries are quite broad at the base of the rostrum, but become quite thin along their lateral borders. The dorsal surface of each of these bones is slightly convex and slopes from the level of the maxillary-premaxillary suture to its outer margin. The dorsal ascending process of the maxillary is short and quite narrow, and extends posteriorly as far as the level of the hinder ends of the premaxillaries and nasals. The dorso-internal border of each maxillary is overlain by the corresponding premaxillary. The antorbital notch is limited to the angle formed by the hinder end of the lateral edge with the rounded and dorso-ventrally thickened postero-external angle of the maxillary. At least two foramina are present in each maxillary 20 mm. external to maxillary-premaxillary suture, one behind the anterior end of the nasals, the other 50 mm. anterior to the nasals. The internal face of the hinder half of the maxillary abuts against the outer surface of the trough-like vomer.

In front of the vomer (which extends forward, as restored, for a distance of 960 mm., but probably originally only 740 mm. in front of anterior ends of nasals), each premaxillary commences to curve downward and inward at a point 850 mm. anterior to anterior ends of nasals to meet its fellow on the mid-line of the rostrum. The vomer behind and the premaxillaries in front thus contribute the floor and the sides of the dorsal narial gutter. The anterior ends of both premaxillaries are imperfectly preserved, but have been restored as shown on the photograph (pl. 1). They attain their maximum width (73± mm.) at the level of the anterior ends of the maxillaries. In their present condition, the dorso-internal edges of the premaxillaries are irregularly curved, but originally undoubtedly paralleled one another from extremity of rostrum to anterior end of dorsal narial fossa, where they are bent downward, and are also curved outward and inward to conform to the contour of the dorsal narial fossa. The much narrower facial or ascending process of the premaxillary is lodged in a groove which follows the dorso-internal angle of the hinder end of the maxillary (at least coextensive with the nasals) and it terminates at the level of the posterior ends of the nasal bones. The hinder end of the premaxillary is lodged also in grooves on the narial process of the frontal. The dorsal surface of the premaxillary in front of the dorsal narial fossa shows a slight convexity in a transverse plane, but more anteriorly it is noticeably flattened and projects forward beyond the maxillary.

On this skull the backward thrust of the median portion of the rostrum has carried the ascending processes of the maxillaries and premaxillaries as well as the nasals backward to the level of the center of the orbit.

The dorsal narial fossa is deep, elongate and quite narrow, the maximum transverse diameter at a point about 150 mm. in front of the anterior ends of the nasal bones being 83 mm. The maximum antero-posterior diameter of this fossa is approximately 370 mm.

The relatively long nasal bones taper from their anterior toward their posterior ends and are wedged in between the ascending processes of the premaxillaries. Their hinder ends are mortised into the narial process of the combined frontals and anteriorly they overhang the dorsal narial fossa. The nasals do not project backward beyond the level of the hinder ends of the ascending processes of the maxillaries and premaxillaries. The antero-external angles of the nasals project forward slightly beyond the medial portions of these elements, forming a concavely curved anterior face.

The frontals are exposed to a very limited extent in the median interorbital region and are excluded from the vertex by the parietals. They present a median exposure of approximately 23 mm. between the hinder ends of the over-riding medial rostral elements and the intertemporal constriction formed by the parietals. The frontals slope regularly from the high interorbital region toward the orbital rim of their supraorbital processes. The narrower anterior portion of the dorsal surface of the supraorbital process is separated from the broader and less obliquely downward sloping hinder portion by a curved transverse temporal crest. The preorbital angle of this process is rounded and the robust postorbital projection is extended outward. The orbital end of this supraorbital process is quite thin and is arched.

The lachrymal is not preserved on either side. On the left side of this skull, there is some evidence to indicate that this plate-like element was wedged in between the postero-external angle of the maxillary and the preorbital angle of the supraorbital process of the frontal.

The maxillaries may possibly over-ride the antero-lateral borders of the frontals to a slight extent, although the exposed surfaces of the latter exhibit no evidence of such a contact. Posteriorly, the frontals are suturally united with the parietals at the anterior end of the intertemporal constriction. The rostral wall of the cranium is formed largely by the frontals.

The parietals, which meet medially to form a very short intertemporal constriction, are overriden above and behind by the large triangular supraoccipital shield. Anteriorly, the thin narrow process of the parietal, which overrides the base of the supraorbital process, extends forward almost to the level of the hinder margins of the ascending processes of the maxillaries. The parietal as a whole is rather broad dorso-ventrally and lies for the most part below the level of the lambdoidal crest. It constitutes the major portion of the nearly vertical lateral wall of the braincase. Behind the level of the hinder edge of the supraorbital process, the lower edge of the parietal anteriorly is suturally in contact with the dorsal edge of the alisphenoid and, behind the latter, the suture between the parietal and the squamosal curves outward, then upward, and backward to meet the supraoccipital on the lambdoidal crest. The dorsal edge of the parietal constitutes the overhanging outer face of the lambdoidal crest which is essentially complete.

The squamosal is the large thick bone which constitutes the conspicuous postero-lateral portion of the skull. The strongly oblique anterior face of the squamosal, which constitutes the major portion of the hinder wall of the temporal fossa, curves backward, outward, and forward from the alisphenoid to the end of its zygomatic process. On the left side, the zygomatic process is destroyed and the portion of the lambdoidal crest, which follows along the hinder and outer margins of the dorso-posterior portion of the squamosal, is eroded. The dorsal surface of this portion of the squamosal is strongly concave, forming a large concavity which is bounded above, behind and outside by the lambdoidal crest. The squamosal and parietal, above the level of the zygomatic process, bulge slightly outward. The right zygomatic process is eroded externally. This short process is deeply excavated longitudinally on its internal face, forming an elongate concavity, and is bent strongly outward and forward. It is possible that either erosion or imperfect preservation may have produced this cavity. The zygomatic process is strongly compressed from side to side, and dorsally it is narrowed to form a low longitudinal crest, which is continuous behind with the lambdoidal crest. The lateral portion of the lambdoidal crest overhangs the lateral concavity on the squamosal above the postglenoid process, like in the Modelo cetothere, *Mixocetus elysius*.

From a dorsal view, the occipital condyles appear to be flattened against the basicranium. The exoccipitals are, with the exception of their extreme outer ends, concealed from a dorsal view by the overhanging hinder portions of the lambdoidal crest.

The transverse diameter of the triangular occipital shield at the base is greater than its greatest length. This shield is rapidly narrowed above the level of the condyles to its acutely pointed apex. The forward thrust of the hinder elements in the cranium has not carried the apex of the supraoccipital shield forward to the level of the hinder margins of the supraorbital processes.

Posterior view—The triangular shield (pl. 4), which forms practically all of the hinder wall of the braincase, consists of the medially depressed supraoccipital above and the large antero-posteriorly thickened exoccipitals. For the most part the lambdoidal crests are exceptionally well preserved. On each side, these lambdoidal crests curve upward and forward to the acutely pointed apex, which is depressed slightly below the level of these crests. From the longitudinal median line, the hinder surface of the supraoccipital rises obliquely and with very slight convexity to the lambdoidal crest.

The exoccipitals are the large massive bones which comprise the lateral wings of the posterior triangular occipital shield. These elements are thickened antero-posteriorly and their external angles project backward at least 15 mm. beyond the level of the hinder faces of the occipital condyles. A slight paroccipital process is developed. On each side of the median basicranial depression is a large, rounded, antero-posteriorly elongated and downwardly projected lateral protuberance of the basioccipital. The external face of this lateral protuberance constitutes the inner wall and the paroccipital process the outer wall of the large notch for the jugular leash. These lateral protuberances modify the ventral profile of the skull.

The rather large postglenoid process, which projects laterally beyond the outer edge of the exoccipital, extends ventrally 112 mm. below the level of the ventral face of the right occipital condyle and 80 mm. below the level of the ventral edge of the right exoccipital.

Lateral view—The apex of the supraoccipital shield forms the highest point in the dorsal profile (pl. 3), although it is only slightly higher than the point where the opposite transverse temporal crests on the supraorbital processes converge on the vertex and, in front of the latter, the dorsal profile of the median interorbital region and of the rostrum slopes gradually forward and downward to the extremity of the rostrum.

The rostrum is rather deep proximally at the level of the anterior ends of the palatines and gradually decreases in depth anteriorly. The outer edge of the maxillary is quite thin throughout its length.

The orbital border of the supraorbital process is dorso-ventrally compressed and arched in a fore-and-aft direction. Its preorbital angle is bluntly rounded and is obliquely truncated toward the postero-external angle of the maxillary. The postorbital projection is slightly deeper dorsoventrally (41 mm.) than the preorbital angle. The supraorbital process as a whole slopes downward from the interorbital region to the orbital rim, and the broader hinder region is set off from the narrower anterior region by a prominent curved temporal crest.

The zygomatic process of the squamosal is noticeably deepened dorsoventrally, the concave curvature of its ventral profile being less obvious at the level of the glenoid angle of the squamosal. The dorsal profile of the zygomatic process rises gradually behind its anterior end and merges posteriorly with the outwardly overrolling lateral crest on the squamosal, which in turn is continuous behind with the short forward projection of the lambdoidal crest. Viewed from the side, the postglenoid swells out postero-externally, forming a rounded protuberance, but the concealed hinder surface is somewhat concave. The right zygomatic process is obviously somewhat eroded, since it is perforated from side to side by an elongated opening. It is therefore difficult to determine the genuineness of the concave depression on the internal face of this process. The squamosal as a whole is rather large and constitutes a considerable portion of the lateral wall of the braincase. It is strongly depressed between the hinder portion of the lambdoidal crest and the low lateral crest which is continuous anteriorly with the dorsal edge of the zygomatic process. This low lateral crest overhangs a shallow concavity on the external face of the squamosal above the postglenoid process. Posteriorly, the squamosal is broadly sutured to the anterior surface of the corresponding exoccipital.

The more or less vertical parietal is concavely curved from end to end and constitutes the major portion of the lateral wall of the braincase. It meets the parietal on the opposite side of the cranium to form the short and very narrow isthmus or intertemporal constriction which connects the occipital portion of the skull with the facial or interorbital portion. The dorsal and hinder edges of the parietal form a continuous curve, which is overlain by the lateral edge of the supraoccipital shield, the apex of which does not extend forward to the level of the anteriormost portions of the hinder margins of the supraorbital process.

The occipital condyles are not visible when the skull is viewed from the side. The ventral profile of the maxillaries in the interval where they are overlain by the palatines displays a concave curvature in a fore and aft direction, when viewed from the side.

The alisphenoid appears on the temporal wall of the braincase as an irregularly shaped element and is located behind the base of the postero-internal angle of the supraorbital process, but above the pterygoid. The exposed end of the alisphenoid is more or less subpyriform in outline, the greater length being in the antero-posterior direction (antero-posterior diameter, 73.5 mm.; vertical diameter, 42 mm.). In the temporal fossa, the alisphenoid is bounded dorsally and anteriorly by the parietal, posteriorly by the squamosal, and ventrally by the pterygoid. The boundaries of the alisphenoid are quite distinct.

Ventral view—The under surface of this skull is fairly well preserved (pl. 2), with the exception of the left maxillary and the distal ends of the premaxillaries. As a result of crushing, the opposite maxillaries and premaxillaries have spread apart along the median longitudinal axis of the rostrum, exposing a considerable portion of the trough of the vomer.

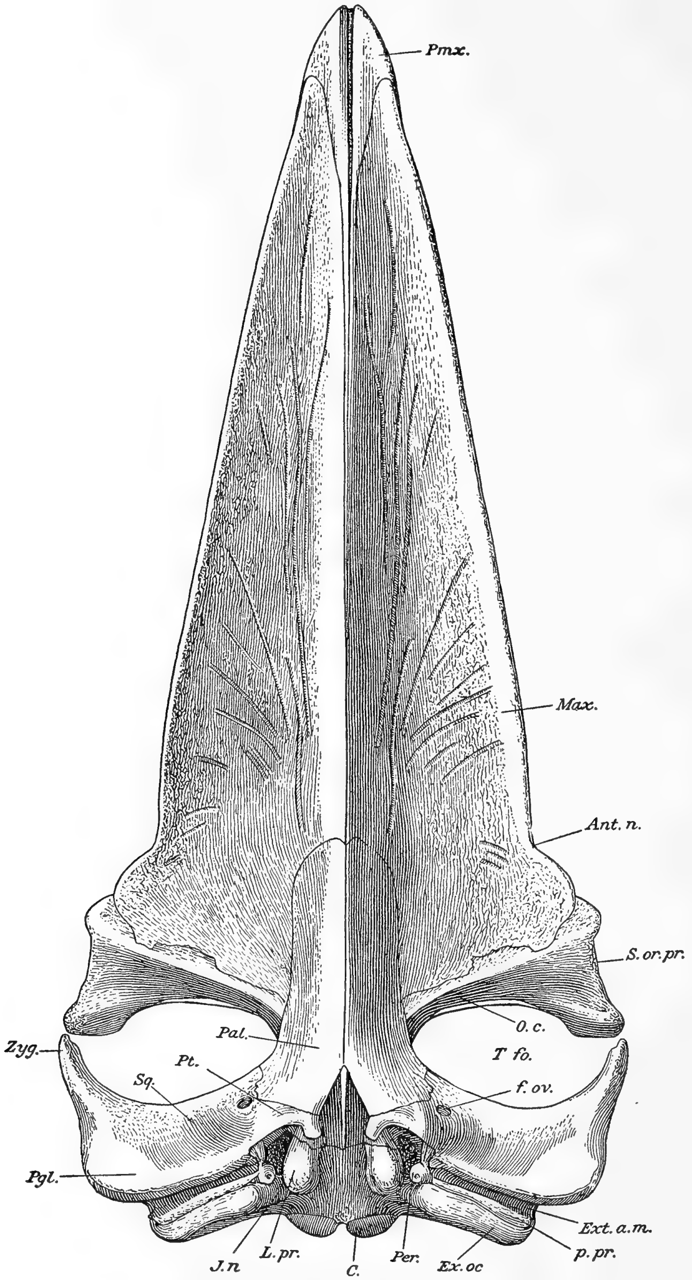

Fig. 2—Ventral view of skull of *Aglaocetus moreni* (Lydekker) corrected for distortion, No. P. 13407, Field Mus. Nat. Hist., Chicago. 1/12 nat. size. (For explanation of abbreviations, see fig. 1.)

The horizontally expanded maxillaries constitute the major portion of the palatal surface of the skull (fig. 2). On the hinder portion of the rostrum, the palatal surface of each maxillary is noticeably concavely curved from side to side. It exhibits a distinct tendency toward a lateral flattening distally, but throughout its length there is a downward and inward convex curvature where it is applied medially to the under surface of the trough-like vomer. There is also a series of shallow, narrow and slightly curved grooves which are directed forward in a more or less oblique direction from the inner to the outer margins of the palatal surface of this bone. The grooves on the hindermost portion of the maxillary are quite short and are directed more obliquely outward. These vascular grooves supply the ligamentary tissues as well as the blades of baleen which are attached to the roof of the mouth. A thin hinder plate of the maxillary was thrust backward, as is shown on the left side, below the supraorbital process of the frontal almost to the level of the ventral channel for the optic nerve.

Anteriorly, there is positive evidence of the exposure of the premaxillaries on the ventral surface of the skull. The right maxillary terminates with certainty at a point 1110 mm. anterior to the level of the antorbital notches. The distance from the anterior end of the right maxillary to the anterior edge of the optic canal at the base of the right supraorbital process is 1370 mm. The inner margins of the maxillaries are spread apart throughout their length, exposing the median longitudinal ridge of the vomer. The inner margins of the maxillaries seemingly commence to diverge at a point 660 mm. behind the level of the anterior end of the right maxillary. Between the anterior end of the vomer and the extremity of the rostrum (a distance of 415 mm. to anterior end of right premaxillary as restored), the premaxillaries, making the necessary allowance for obvious separation due to crushing, apparently meet ventrally along the median longitudinal axis of the rostrum to constitute a complete floor for the distal end of the dorsal narial gutter.

The trough of the vomer is widest at the level of the anterior ends of the palatines. The ventral surface of the vomer may have been concealed by the close approximation of the palatines, because the ventral ridge of the vomer disappears at a point 450 mm. anterior to its hinder end and its rounded ventral surface is distinctly flattened for a distance of 280 mm. backward. The distance from anterior edge of the palatine to point of posterior divergence is apparently 290 mm. At this point, also, the vomer develops a 32-mm. high and 20-mm. wide (at palatal level) longitudinal carina, which constitutes the median partition between the internal choanæ. The ventral edge of this carina extends backward at almost the same horizontal level for a distance of 55 mm. and then diminishes in height rather rapidly to its posterior end which coincides with the hinder end of the vomer. The horizontal distance from the hinder end of the vomer to the assumed point of divergence of the inner edges of the palatines is 167 mm. The hinder horizontally expanded thin plate of the vomer is applied to the ventral surface of the basisphenoid and overrides the anterior border of the basioccipital and, in front of the former, it encircles the ventral and lateral surfaces of the presphenoid. Externally this horizontally expanded plate of the vomer is suturally united with the vaginal process of the corresponding pterygoid along each lateral margin.

The palatines are largely destroyed, with the exception of some remnants attached to the under surfaces of the trough-like vomer. Externally each palatine was mortised into the inner border of the corresponding maxillary for approximately two-thirds of its length. For a very short distance, it was apparently in contact with the under surface of the frontal below the optic foramen and contributes the ventral boundary of this orifice. Behind the postero-internal angle of the supraorbital process, the outer edge of the palatine is suturally united with the pterygoid as far posteriorly as the contact of the latter with the anterior end of the squamosal on the inner wall of the temporal fossa. The thin posterior end of the palatine likewise overspread the pterygoid.

The frontals (fig. 2) are extended outward to form the distally expanded supraorbital processes. The channel for the optic nerve commences at the oval optic foramen and extends transversely across the under surface of the supraorbital process, becoming conspicuously wider toward the orbital rim of this process. Near its origin this channel is limited to the hinder face of the supraorbital process for a distance of probably 50 mm. and then is twisted downward until it is wholly upon the under surface of the supraorbital process. It increases from a minimum width of 15 mm. to a maximum of 137 mm. at the orbital rim of this process. This channel is bounded in front by a high thin crest which at the base constitutes the ventral wall of the optic canal and the anterior boundary from there on toward its orbital end. A high curved osseous crest, which follows the hinder margin of the supraorbital process constitutes the hinder boundary for this channel.

The basioccipital, viewed from the ventral side, is a rectangularly shaped bone, with its long axis transverse to longitudinal axis of the skull. The basioccipital is ankylosed in front with the basisphenoid, the line of contact being overspread by the horizontally expanded posterior end of the vomer. On each side in front of and extending externally beyond the occipital condyle is a very large, rounded and antero-posteriorly elongated descending protuberance. These enlarged lateral protuberances of the basioccipital greatly reduce the transverse diameter of the median basicranial depression. The minimum transverse distance between the inner faces of these protuberances does not exceed 75 mm. The somewhat flattened external surfaces of these lateral protuberances slope obliquely downward. The anterior face of each lateral protuberance is fused with the corresponding vaginal process of the pterygoid, but the line of sutural contact, which is on a line with hinder end of vomer, can be determined with fair certainty on both sides. The ventral surface of the vaginal process of the pterygoid curves downward to conform to the curvature of the corresponding surface of the lateral protuberance.

The basisphenoid is a flat rectangular bone, the greater length being in the antero-posterior direction. It is entirely concealed by the horizontally expanded hinder plate of the vomer. Anteriorly, this element is suturally united on each side with the vaginal process of the pterygoid.

The vaginal process of the pterygoid is preserved in its entirety on the right side and is slightly damaged on the left side. This process is suturally united along its dorsal edge with the outer edge of the basisphenoid. Along its dorso-internal margin it meets or is ankylosed to the horizontally expanded hinder plate of the vomer. The hinder end of this vaginal process, as mentioned previously, overlaps the anterior face of the lateral protuberance of the basioccipital. These vaginal processes of the opposite pterygoids take part in the formation of the lower boundaries of the internal choanæ and, in conjunction with the lateral protuberances of the basioccipital, bound the median region of the basicranium.

The narrow and elongated pterygoid fossa (pl. 2), as its name implies, is bounded internally by the vaginal process of the pterygoid, anteriorly and antero-externally by the downward curvature of the thickened anterior and outer borders of the pterygoid and postero-externally by the short and rather narrow falciform process of the squamosal. The roof of this fossa is constituted by a thin plate of the pterygoid, and the floor or ventral wall (fig. 2) was no doubt contributed by an inwardly and backwardly curved hamular process of the pterygoid, but this is destroyed on both sides. The hinder end of the pterygoid fossa is not closed over by any bony plate or process, but is continuous with the tympano-periotic recess. The rather large tympano-periotic recess opens into the interior of the cranium. This recess is bounded by the squamosal and its falciform process externally, by the alisphenoid and the underlying thin plate of the pterygoid anteriorly, by the lateral protuberance of the basioccipital internally and by the exoccipital posteriorly.

The posterior lacerated foramen for the jugular leash occupies a broad notch which is located at the postero-internal angle of the tympano-periotic recess. This notch is bounded by the lateral protuberance of the basioccipital internally and by the exoccipital externally and superiorly. The transverse diameter of this notch at its ventral limit is 38 mm.

On the ventral surface, the contact between the squamosal and the exoccipital lies above the posterior process of the periotic, and the latter is wedged in between these two elements. Between the posterior process of the periotic and the base of the hinder face of the postglenoid process is a narrow transverse channel for the external auditory meatus, which widens externally. This channel, which is directed at an oblique angle to the longitudinal axis of the skull, originates at the inner edge of the squamosal and extends outward largely on the ventral surface of the posterior process of the periotic. The right squamosal is very well preserved, but the left one lacks its zygomatic process.

The right zygomatic process is attenuated from the base toward the extremity and its outer profile, viewed from below, exhibits a slight convex curvature from end to end. It is somewhat eroded, as has been described previously. The postglenoid process projects downward at least 58 mm. below the level of the right lateral protuberance of the basioccipital. This process is very robust, with a concavely curved hinder face, a more or less flattened anterior face which slopes obliquely upward from its median longitudinal ventral axis to its outer margin, and also curves concavely upward to the inner concave glenoid fossa for articulation with condyle of mandible. The external surface of this process is somewhat rounded.

External to the anterior process of the periotic, the ventral surface of the squamosal is hollowed out, forming a large broad concavity, which extends forward obliquely from the postero-internal angle of the postglenoid process to near the glenoid angle of the squamosal, and also downward upon the internal face of the postglenoid process. The maximum transverse diameter of glenoid fossa on the right side is 143 mm., and its maximum oblique antero-posterior diameter is 128 mm.

On the ventral surface of the skull, the squamosal forms the outer and the major portion of the hinder boundary of each temporal fossa, the internal margin being coextensive with the outer edge of the palatine.

External to the pterygoid fossa and behind the postero-external angle of the palatine, is a large orifice, the foramen ovale. This foramen is located in the bifurcation between the falciform and glenoid processes of the squamosal, which are suturally united in front with the pterygoid. The maximum antero-posterior diameter of the foramen ovale is 36± mm., and its maximum vertical diameter is 15 mm. The falciform process of the squamosal is convex in both directions, and its internal border overhangs a portion of the tympano-periotic recess, as well as the hinder end of the pterygoid fossa.

The large thickened exoccipitals constitute the hinder boundary of the ventral face of the skull. The paroccipital processes are merely rounded modosities which are prolonged ventrally slightly below the level of the ventral edge of the exoccipital. The occipital condyles are separated medially by a narrow notch.

Measurements of skull (in millimeters)

Greatest length of skull, anterior end of right premaxillary to level of postero-external angles of exoccipitals	1905±
Distance between anterior end of right premaxillary and posterior surface of right occipital condyle	1890±
Distance between anterior end of right premaxillary and apex of supraoccipital shield	1600±
Length of rostrum, level of antorbital notches to anterior end of right premaxillary	1310±
Greatest length of right premaxillary	1515±
Distance between anterior end of right premaxillary and anterior end of right nasal bone	1280±
Distance from apex of supraoccipital shield to posterior end of right nasal bone	84
Greatest length of right nasal bone	238
Transverse diameter of right nasal bone, anteriorly	20.6
Transverse diameter of right nasal bone at hinder end	11.8
Combined width of nasal bones, anteriorly	44.5
Combined width of nasal bones at hinder ends	36.2
Transverse distance between outside margins of premaxillaries at level of anterior ends of nasal bones	104
Maximum transverse distance between outside margins of premaxillaries at level of anterior ends of maxillaries	160±
Transverse diameter of rostrum at level of antorbital notches	577
Transverse diameter of skull across preorbital angles of supraorbital processes	780
Transverse diameter of skull across postero-external angles of supraorbital processes	860±
Greatest antero-posterior diameter of right supraorbital process	223.5
Transverse diameter of skull between outer surfaces of zygomatic processes	800±
Transverse diameter of skull between outer margins of exoccipitals	580
Transverse distance between outer margins of occipital condyles	157.8
Greatest or obliquo-vertical diameter of right occipital condyle	95.5
Greatest transverse diameter of right occipital condyle	70
Vertical diameter of foramen magnum	50±
Transverse diameter of foramen magnum	47
Distance from upper margin of foramen magnum to apex of triangular supraoccipital shield	330
Vertical distance from vomer on basisphenoid to apex of supraoccipital shield	208
Greatest length of right zygomatic process, extremity of postglenoid process to anterior end of zygoma	325
Greatest breadth of basioccipital across lateral protuberances, outside measurement	180
Least intertemporal diameter of cranium on ventral face	190
Least intertemporal diameter of cranium on dorsal face	17
Greatest antero-posterior diameter of right palatine bone	360±
Distance from posterior end of vomer to anterior end of right palatine bone	460±
Greatest antero-posterior diameter of right pterygoid fossa	94±
Greatest transverse diameter of right pterygoid fossa	56

MANDIBLES

The mandibles (pl. 3) of this cetothere are shorter and slenderer than those of *Mixocetus elysius,* and are much less robust than those of the Calvert Miocene *Cetotherium cephalum* (Cat. No. 11976, U. S. Nat. Mus.). Both of these mandibles are exceptionally well preserved.

The horizontal rami of these mandibles are strongly bowed outward and the maximum distance between the opposite alveolar margins is considerably greater than the width of the rostrum at the corresponding level (pl. 4). The internal surface of each mandible is distinctly flattened and the external surface is rather strongly convex. The relatively short symphyseal region is pitted for the attachment of ligaments.

The internal series of small foramina is located in the longitudinal groove which follows the alveolar edge of the mandible. The external series of mental foramina are relatively large and drop down to a lower level toward the anterior end of the mandible. Each of these foramina opens into a groove, which not only is directed anteriorly but also increases in width from its point of origin to the level where it becomes indistinct.

The coronoid process is a low outwardly curved projection, with apex slightly behind level of anterior edge of the internal orifice for the large mandibular canal. The anterior margin of the low coronoid process rises rather gradually and its hinder margin descends abruptly.

The condyle is strongly compressed from side to side (pl. 4) and is likewise convex. Below the center, the condyle narrows rapidly toward its ventral limit and possesses a distinct furrow on the internal face above the ventral border.

Measurements of right mandible (in millimeters)

Greatest length of mandible along outside curvature	1860
Greatest length of mandible in a straight line	1800
Greatest vertical diameter of mandible at level of symphysis	128.5
Greatest transverse diameter of mandible at level of symphysis	48
Greatest vertical diameter of mandible at a point 780 mm. anterior to hinder face of condyle	133.5
Greatest vertical diameter of mandible at coronoid process	217
Least vertical diameter of mandible behind coronoid process	152
Greatest vertical diameter of condyle	190
Greatest transverse diameter of condyle	83.2

REMARKS

Dr. Cabrera[1] has recognized three categories of cetotheres and formulated the following diagnoses.

In the first group, the maxillaries, premaxillaries and nasals penetrate deeply between the frontals, forming a "kind of cradle," and the zygomatic processes project relatively little outward. *Cetotherium rathkii* is a typical representative of this group.

In the second group, the maxillaries, premaxillaries and nasals do not penetrate so much between the frontals, but keep their posterior borders almost in a nearly transverse plane, and the zygomatic processes are very divergent and strongly bent, projecting noticeably

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[1] A. Cabrera, *op. cit.,* 369-370, 1926.

outward. This group includes *Plesiocetus, Idiocetus, Mesocetus, Isocetus* and *Metopocetus.* Cabrera refers *Cetotherium moreni* Lydekker to the genus *Plesiocetus.*

In the third group, the relations of these elements resemble the second group, except that the brain case is much elevated, the condyle of the mandible is strongly compressed and is very deeply furrowed on its internal face near the lower border. *Heterocetus* and *Amphicetus* are assigned to this group.

The first group established by Cabrera is recognized by the writer as valid and is characterized as follows: Apex of supraoccipital shield thrust forward beyond level of hinder parietal margin of temporal fossa; nasals located entirely behind level of preorbital angles of supraorbital processes; thin anterior process of parietal, which overrides basal portion of supraorbital process, not extended forward to level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries and the nasals); and the backward thrust of the rostrum has carried the hinder ends of the median rostral elements to or beyond level of anteriormost portion of hinder edge of supraorbital process.

In the writer's judgment, Cabrera's diagnoses for the second and third groups will not stand close scrutiny for the skulls of the cetotheres included in these categories represent several rather widely separated stages in the remodeling or telescoping of this type of cranium.

On the basis of criteria such as are here employed, *Metopocetus durinasus* represents a more advanced stage than *Mesocetus longirostris,* but both are quite closely allied. They possess in common the following combination of characters: Apex of supraoccipital shield not thrust forward beyond level of hinder parietal margin of temporal fossa; nasals apparently located entirely behind level of preorbital angles of supraorbital processes; thin anterior process of parietal, which overrides basal portion of supraorbital process, extended forward beyond level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries, and the nasals); and the backward thrust of the rostrum seemingly has carried the hinder ends of median rostral elements to or beyond level of anteriormost portion of hinder edge of supraorbital process.

Conversely, *Idiocetus laxatus* is characterized by having the apex of the supraoccipital shield thrust forward to level of anterior ends of zygomatic processes; the nasals are located in part anterior to the level of preorbital angles of supraorbital processes; the thin anterior process of the parietal, which overrides the basal portion of supraorbital process, not extended forward to level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries and the nasals); and the backward thrust of the rostrum has carried the hinder ends of median rostral elements distinctly beyond level of preorbital angles of supraorbital processes, but not to level of center of orbit. Although the skull of the genotype of *Idiocetus*,[1] *I. guicciardinii* Capellini, is very imperfectly known, the periotic and tympanic bones, as well as the supraoccipital shield, indicate that it represents a fossil finback whale and that it should be allocated to the family Balænopteridæ. The species described by van Beneden as *Idiocetus laxatus* and *Idiocetus longifrons* are unquestionably cetotheres and can not therefore be allocated to the genus *Idiocetus*. The skull of *Isocetus depauwii* is unknown.

Inasmuch as van Beneden[2] in 1872 restricted the application of *Plesiocetus* to the species *garopii*, a balænopterine whale, this name is not available for any cetothere. Brandt[3] in 1873 proposed a new subgenus, *Plesiocetopsis*, to include *Plesiocetus hupschii*, *Cetotherium brevifrons*, *Cetotherium dubium*, *Plesiocetus burtinii* and *Plesiocetus gervaisii*. The writer[4] has selected *Plesiocetus hupschii* as the genotype of *Plesiocetopsis* and has pointed out that the co-types of this species were deposited in the "Musée de l'Université Catholique, Louvain." One of these is an imperfect basicranium which has been figured by van Beneden.[5] The periotic, as figured, is quite unlike the periotic identified as *Plesiocetus hupschii* by van Beneden[6] in 1885. It is quite likely that the figured co-type skull and the imperfect cranium with associated periotic allocated to this species in 1885 actually represent two distinct cetotheres. Furthermore, the supraoccipital shield as well as the intertemporal and frontal regions of the figured co-type skull are missing. van Beneden's *Plesiocetus burtinii* is likewise imperfectly known; the entire frontal region and the rostrum are missing. Thus the genera *Plesiocetopsis* [=*Plesiocetus* Auct.] and *Isocetus* can not be allocated at present on the basis of interdigitation of the rostral and the cranial elements to any one of the three groups proposed by Cabrera. Furthermore, *Mesocetus* and *Metopocetus* are structurally quite different from van

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[1] G. Capellini, *Balene fossili Toscane. III: Idiocetus guicciardinii*, Mem. R. Accad. Sci. Bologna (6), vol. 2, 71-80, pls. 1-2, 1905.

[2] P. J. van Beneden, Bull. Acad. Roy. Sci. Belgique (2), vol. 34, No. 7, 242, 1872.

[3] J. F. Brandt, Mém. Acad. Imp. Sci. St. Pétersbourg (7), vol. 20, No. 1, 144, 1873.

[4] R. Kellogg, Proc. Calif. Acad. Sci. (4), vol. 19, No. 12, 315, 1931.

[5] P. J. van Beneden and Paul Gervais, Ostéographie des Cétacés, Paris, Atlas, pl. 16, fig. 17, 1872.

[6] J. P. van Beneden, Ann. Mus. Roy. d'Hist. Nat. Belgique. Bruxelles, vol. 9, pl. 21, figs. 2-7, 1885.

Beneden's *"Idiocetus."* They possess characters that Cabrera assigns to his first group.

No exception can be taken to most of the characters cited by Cabrera for his third group, providing this group is arbitrarily restricted to the species proposed by van Beneden. The genotype of *Heterocetus, H. guiscardii* Capellini,[1] comes from the upper Lower Pliocene of Briatico, province of Naples, Italy. This species is based on an incomplete left mandible, the left tympanic bulla, the anterior and posterior process of the periotic, the stapes, the third to seventh cervicals inclusive, and several ribs. When the description and accompanying illustrations for *Heterocetus guiscardii* Capellini are compared with those for van Beneden's *Heterocetus affinis, H. brevifrons* and *H. sprangii,* it is difficult to recognize any indication of generic similarity. The tympanic bulla of *Heterocetus guiscardii* is certainly unlike those of van Beneden's species and unfortunately the condyle of the mandible is missing.

It is by no means certain that all of the material referred by van Beneden [2] to *Amphicetus later,* the genotype, is correctly allocated. In the original description, van Beneden [3] states that the frontal resembles that of *Heterocetus* [=*"Plesiocetus"*] *burtinii,* but the tympanic bulla is smaller and wider and the parietals are elongated. van Beneden lists a portion of a cranium as well as some tympanic bullæ and periotics. Additional specimens were allocated to this species by van Beneden in 1886. The original cranial fragment (Cat. No. 275, Musée royal d'histoire naturelle de Belgique), the tympanic bullæ and the periotics are all co-types. The specimens subsequently described by van Beneden are merely referred specimens. This original cranial fragment of *Amphicetus later* shows that the interdigitation of rostral and cranial portions of the skull is similar to that of *Mesocetus longirostris,* for the thin anterior process of the parietal, which overrides the basal portion of the supraorbital process of the frontal, is extended forward beyond the level of the hinder ends of the median rostral elements (ascending processes of maxillaries and of premaxillaries, and the nasals). This region is missing on *Heterocetus brevifrons,* imperfectly preserved on *H. sprangii,* and essentially the same as *Idiocetus laxatus* on *H. affinis.* It is quite possible that the mandibles, on which Cabrera in part based his diagnosis, are incorrectly identified since most of them are

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[1] G. Capellini. Atti. R. Accad. Lincei, mém, cl. sci. fis. (3), vol. 1, 613, pl. 1, figs. 1-15, 1877.

[2] P. J. van Beneden, Ann. Mus. Roy. d'Hist. Nat. Belgique, Bruxelles, vol. 13, 3, pls. 1-3, 1886.

[3] P. J. van Beneden, Bull. Roy. Sci. Belgique, Bruxelles (2), vol. 50, 20, 1880.

referred specimens. On the basis of such comparisons as can be made, it is obvious that at least two distinct types of cranial architecture are represented.

The genus *Cetotheriopsis* was proposed by Brandt[1] for *Balænodon lintianus* H. von Meyer which was found in the Aquitanian white sands in the vicinity of Linz, Austria. *Cetotheriopsis lintianus* was based on a hinder cranial fragment, comprising the complete triangular occipital shield, the occipital condyles and both zygomatic processes, but the basicranial elements are missing. The limited outward projection of the opposite squamosal portions of the skull as well as the abrupt angle at which the zygomatic processes are directed forward distinguish this species from other known cetotheres. Although the apex of the supraoccipital shield is thrust forward beyond the level of the anterior ends of the zygomatic processes, a distinct intertemporal constriction is retained. The length of the supraoccipital shield and the presence of an intertemporal constriction indicate that the telescoping of this skull was accomplished chiefly by a forward movement of the posterior elements. The extent of the interdigitation of the rostral and the cranial elements is uncertain. Brandt[2] states that the maximum breadth of the cranial fragment is 530 mm. and its greatest length in a straight line is 400 mm. This skull was also examined by van Beneden[3] and he states that the squamosal breadth is 500 mm. and the distance from the hinder surfaces of the occipital condyles to the apex of the supraoccipital shield is 300 mm.

In so far as our present knowledge goes, the Patagonian cetothere skull is separable from that of *Cetotheriopsis lintianus* by the conspicuous outward prolongation of the squamosal portions of the skull, by the outward bowed zygomatic processes, and by the width of the temporal fossæ.

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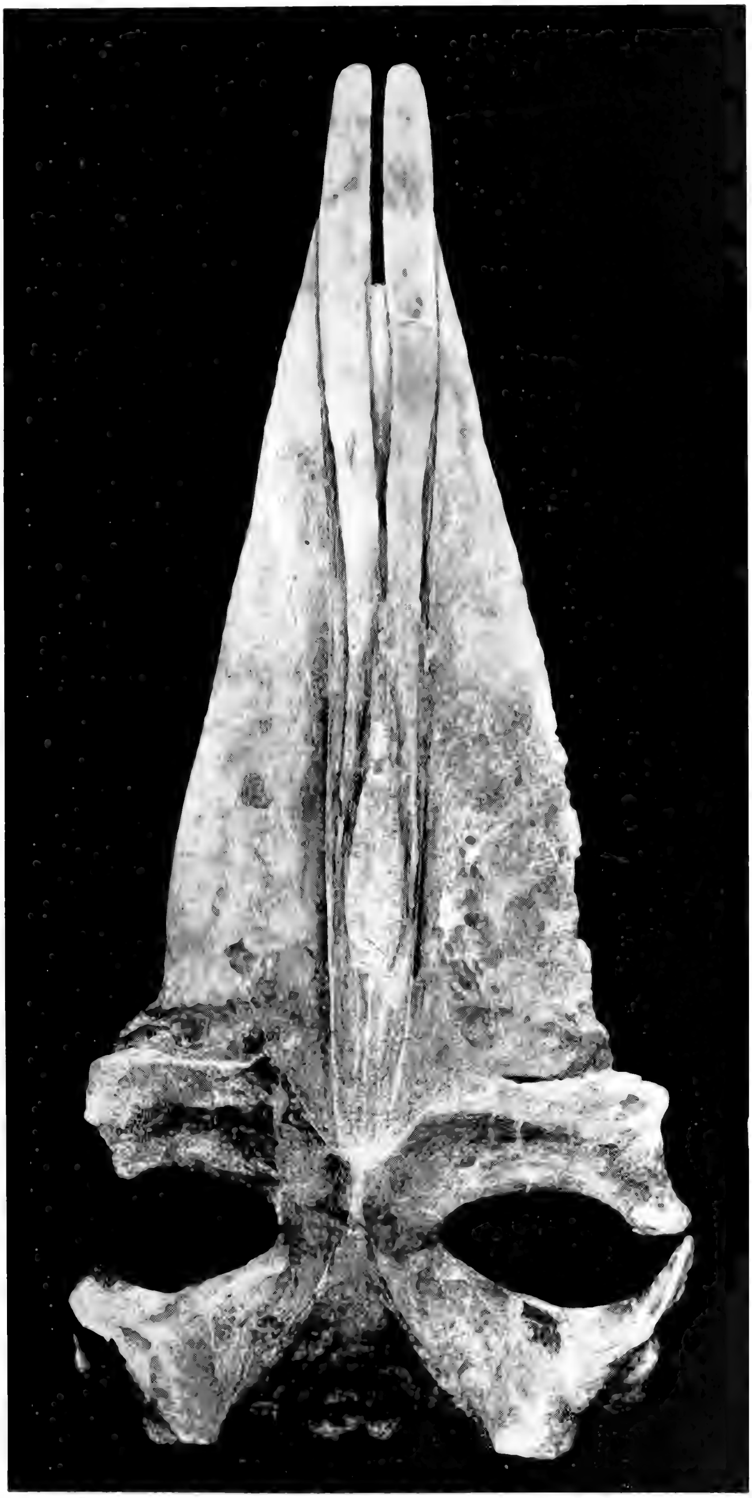
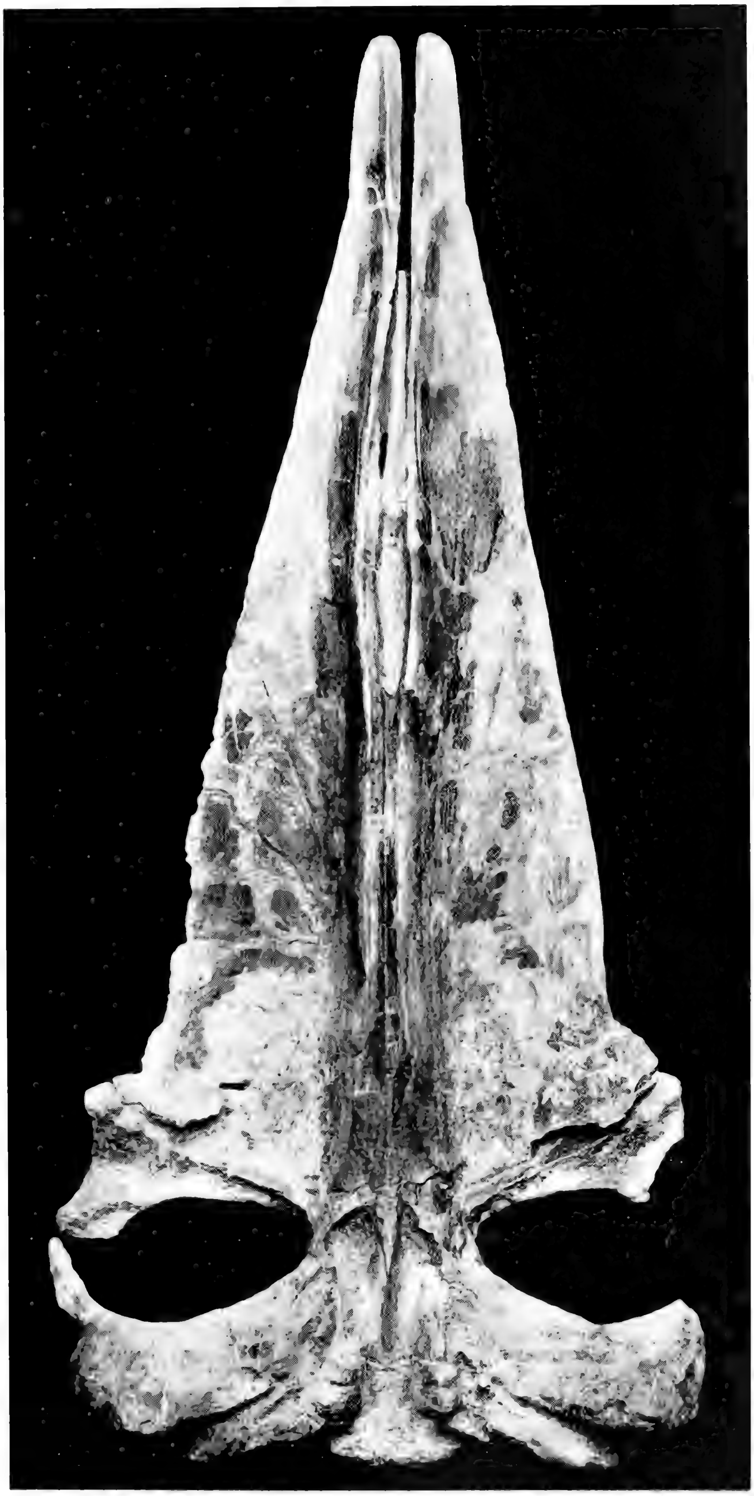
[1] J. F. Brandt, 1871, Mélanges Biol., Bull. Acad. Imp. Sci. St. Pétersbourg, vol. 8, 196 Oct., 1871; Bull. Acad. Imp. Sci. St. Pétersbourg, vol. 16, 566, Nov. 13, 1871.

[2] J. F. Brandt, 1873, Mém. Acad. Imp. Sci. St. Pétersbourg (7), vol. 20, No. 1, 40; see also pl. 19, 1873.

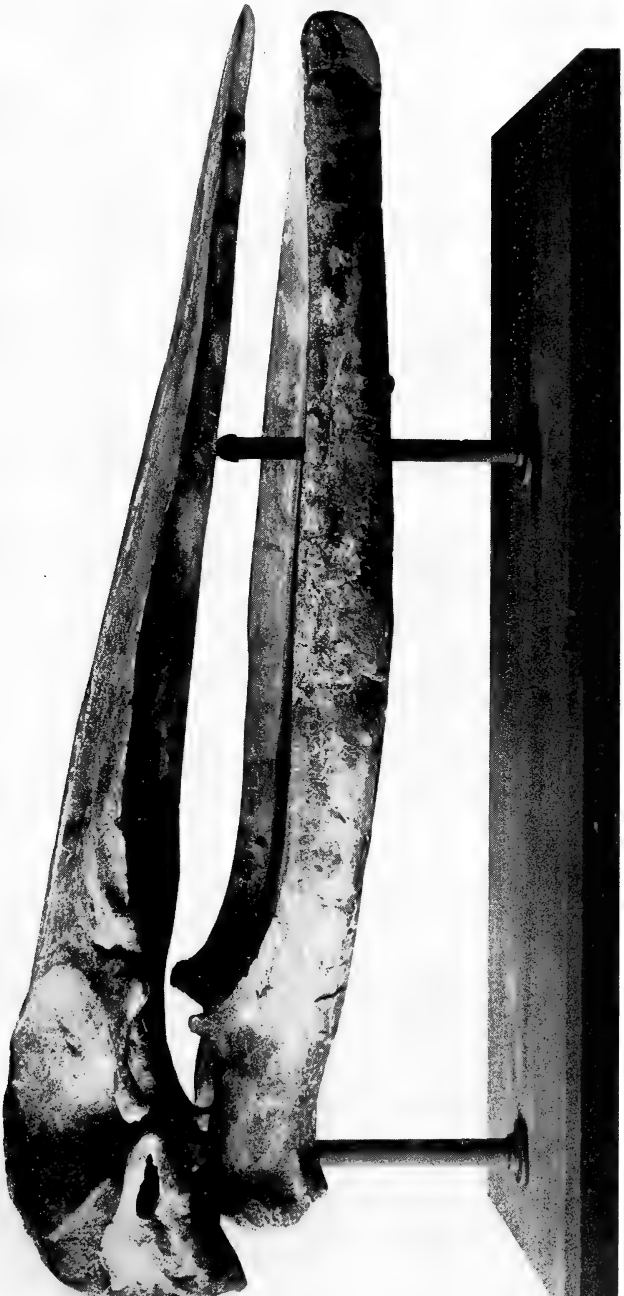
[3] P. J. van Beneden, Mém. Acad. Roy. Sci. Belgique, vol. 35, 75; and pl. 4, vol. 35, 1865.



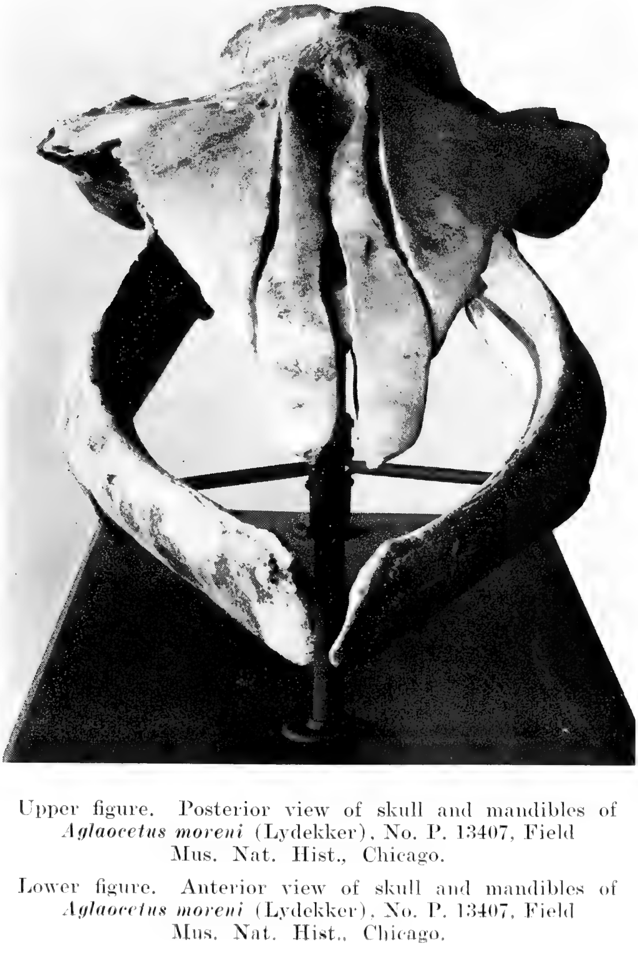
Dorsal view of skull of *Aglaocetus moreni* (Lydekker), No. P. 13407. Field Mus. Nat. Hist., Chicago. 1/10 nat. size.



Ventral view of skull of *Aglaocetus moreni* (Lydekker), No. P. 13407. Field Mus. Nat. Hist., Chicago. 1/10 nat. size.



Lateral view of skull and right mandible of *Aglaocetus moreni* (Lydekker), No. P. 13407, Field Mus. Nat. Hist., Chicago. About 1/12 nat. size.



Upper figure. Posterior view of skull and mandibles of *Aglaocetus moreni* (Lydekker), No. P. 13407, Field Mus. Nat. Hist., Chicago.

Lower figure. Anterior view of skull and mandibles of *Aglaocetus moreni* (Lydekker), No. P. 13407, Field Mus. Nat. Hist., Chicago.

CONTRIBUTIONS TO PALÆONTOLOGY

III

A NEW CETOTHERE FROM THE MODELO FORMATION AT LOS ANGELES, CALIFORNIA

By Remington Kellogg

With one plate and three text-figures

[Issued January 10, 1934]

CONTENTS

A NEW CETOTHERE FROM THE MODELO FORMATION AT LOS ANGELES, CALIFORNIA

INTRODUCTION

On January 22, 1931, F. W. Maley, while digging a ditch preparatory to planting a row of avacado seedlings on land belonging to Mrs. L. W. Blevens in Lincoln Heights, Los Angeles, unearthed a large vertebra. This specimen, weighing 18 pounds, was brought to the Los Angeles Museum by Mr. Maley where it was identified by the assistant vertebrate palæontologist, J. W. Lytle, as the lumbar vertebra of an extinct whalebone whale. Inspection of the site of discovery indicated that additional material might be obtained. Permission for excavation having been granted by Mrs. Blevens, Mr. Lytle with the assistance of William Strong, Lydia Bowen and Henry Wylde started to remove the overburden on January 24, and their efforts were ultimately rewarded by the finding of a series of vertebræ, the skull and both mandibles. The excavation and the preparation of the specimen for removal to the museum required more than two weeks and it was not until February 8 that this task was completed.

Through the kindness of Dr. W. A. Bryan, director, and Dr. Chester Stock, vertebrate palæontologist of the Los Angeles Museum, the writer was invited to study and prepare a description of this specimen. Arrangements made by the United States National Museum and the Carnegie Institution of Washington enabled the writer to visit Los Angeles and complete this cooperative project. Acknowledgments are due to Messrs. Henry Wylde and William Strong for assistance in assembling the material for study. The photographs here published were made by H. W. Menke, and were retouched by John L. Ridgway; the line drawings were made by Sydney Prentice.

MIXOCETUS[1] new genus

Genotype—*Mixocetus elysius* new species.

Diagnosis—Resembling *Mesocetus longirostris*[2] and *Metopocetus durinasus*[3] in the degree of interdigitation of rostral and cranial elements. Differing from these cetotheres in the following peculiarities: Cranium

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[1] μιξο, mixed; κῆτος, whale—in allusion to the combination of characters exhibited by the skull.

[2] P. J. van Beneden, *Description des ossements fossiles des environs d'Anvers, Pt. 5, Genres: Amphicetus, Heterocetus, Mesocetus, Idiocetus and Isocetus,* Ann. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, vol. 13, pl. 34, figs. 1-2, 1886.

[3] E. D. Cope, *Sixth contribution to the knowledge of the marine Miocene fauna of North America,* Proc. Amer. Philos. Soc., vol. 35, No. 151, 141, pl. 11, fig. 3, Aug. 15, 1896.

with supraorbital processes exhibiting a pronounced downward curvature at base; anterior temporal crests less abruptly elevated above level of basal portions of supraorbital processes of frontals; exposure of frontals in median interorbital region reduced to a narrow strip; postglenoid process quite robust, bulging posteriorly; and exoccipital unusually thickened anteroposteriorly.

This cetothere exhibits in addition the following combination of structural characters: Apex of supraoccipital shield not thrust forward beyond level of hinder parietal margin of temporal fossa; nasals located almost if not wholly behind level of preorbital angles of supraorbital processes of frontals; thin anterior process of parietal, which overrides basal portion of supraorbital process, extended forward beyond level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries and nasals); backward thrust of rostrum has carried hinder ends of median rostral elements beyond level of anteriormost portion of hinder edge of supraorbital process; and rostrum exhibits a rather gradual distal attenuation.

Mixocetus elysius new species

Type—Cat. No. 882, Department of Vertebrate Paleontology, Los Angeles Museum of History, Science and Art. The specimen consists of a skull in a fair state of preservation, imperfectly preserved periotics and tympanic bullæ, both mandibles, the left scapula, and twenty-two imperfectly preserved vertebræ, including the third to seventh cervical vertebræ inclusive, twelve consecutive dorsal vertebræ, and five anterior lumbar vertebræ.

Type locality—In uncharted section (? 13) of township 1 south, range 13 west, near summit of hill located between Arroyo Seco and Lincoln Park, Los Angeles, Los Angeles County, California. The specimen was found about 50 or 60 feet west of the home of Mrs. L. W. Blevens at 527 Lincoln Park Avenue and at an elevation of 600 feet. This locality is situated approximately one-fifth of a mile east and about halfway between hills 740 and 657 shown on the Los Angeles Quadrangle, U. S. Geological Survey.

Horizon—This cetothere was found by Mr. F. W. Maley in strata of laminated shale and fine sand. The hinder end of the lumbar series was almost exposed at the surface while the skull was buried to a depth of approximately nine feet.

Dr. William S. W. Kew and Mr. H. L. Driver have examined the locality where this cetothere was collected. They obtained samples of shale containing a good foraminiferal fauna and made several other collections above and below this horizon. The following statement submitted by Dr. Kew summarizes the stratigraphic occurrence of this cetothere.

The whale remains found on the property of Mrs. L. W. Blevens occur in the Elysian Park sandstone member of the Modelo (Puente) formation. It lies in some laminated shale and fine sand strata close to a light-gray platy shale bed in the sandstone. This is about 500′ below the top of this sandstone member. The Elysian Park sandstone member comprises a series (2750′±) of rather massive beds of medium to coarse sandstone in which are thin beds of shale, sandy shale, and fine sandstone usually less than two feet thick. Occasionally beds of fine sandstone, shale and marl are present which have a thickness up to 50 feet. This sandstone represents the oldest rocks in the Los Angeles City area east of the Santa Monica Mountains, or Los Felis Avenue. According to the foraminifera occurring in the lowest exposed beds of the Elysian Park sandstone, it is to be correlated with the Monterey formation of the type section above the top of the *Valvulineria californica* zone. It is therefore younger than the Temblor bone bed. The fauna from the whale locality indicates that the age is the lower part of the upper Miocene.

Field work by Dr. Kew has shown that in the Los Angeles City section proper, at least 5800 feet of Miocene beds overlie the horizon in which this cetothere was found. This horizon in the Elysian Park sandstone member of the Modelo formation is certainly Upper Miocene in age and may possibly be correlated with the Sarmatian stage of Europe.

Skull

This skull is characterized in part by a quite obvious forward thrust of the posterior elements, especially the supraoccipital and the parietals, and a pronounced backward thrust of the anterior elements, which produces a well-marked interdigitation of rostral and cranial elements. This condition represents a somewhat advanced stage in the telescoping of the cetothere skull. The interdigitation of rostral and cranial elements, in conjunction with the extremely short intertemporal constriction and the pronounced downward curvature of the basal portions of the supraorbital processes of the frontals, seem to foreshadow the conditions which characterize the balænopterids, such as the abrupt depression of the supraorbital processes at the base, the exclusion of the parietals from the vertex, and the very limited exposure of the frontals on the interorbital region.

Dorsal view—The rostrum is characterized by a rather gradual distal attenuation in front of the level of the antorbital notches, the transverse diameter at this point being equivalent to 41 per cent of its greatest length. The rostrum alone constitutes 65 per cent of the total length of the skull (fig. 1). The width of the skull in the frontal region is not unusual, since the transverse distance between the postero-external angles of the supraorbital processes is equivalent to two-fifths of the total length of the skull.

The maxillaries are, of course, the largest elements in the skull, forming the major portion of the rostrum. On the dorsal surface, the hinder end of the maxillary broadly overrides the anterior border of the supraorbital process of the frontal and is thrust backward to the level of the curved transverse crest. These curved transverse crests on the dorsal surfaces of the supraorbital processes are generally designed as the anterior temporal crests, since they mark the anterior limits of the areas for the origin of the temporal muscles. With the exception of a small fragment of the outer border, the postero-external angle of the right maxillary is essentially complete. On the left maxillary, behind and external to the level of the antorbital notch, this angle has been shoved forward by pressure. At the time this skull was being prepared for study the existing gap between this angle of the maxillary and the preorbital angle of the supraorbital process was filled with plaster, and consequently this region now appears abnormal on the left side (pl. 1). The rather broad postero-internal end of ascending process of the maxillary is extended backward a few millimeters beyond the level of the hinder ends of the nasal bones. The lateral border of the maxillary is thin and blade-like, and it disappears from view anteriorly on the left side fully 380 mm. behind the anterior end of the premaxillary. In cross-section the hinder half of the maxillary would appear subtriangular in outline. The internal face of the hinder half of each maxillary rests against the ventro-external surface of the trough-like vomer.

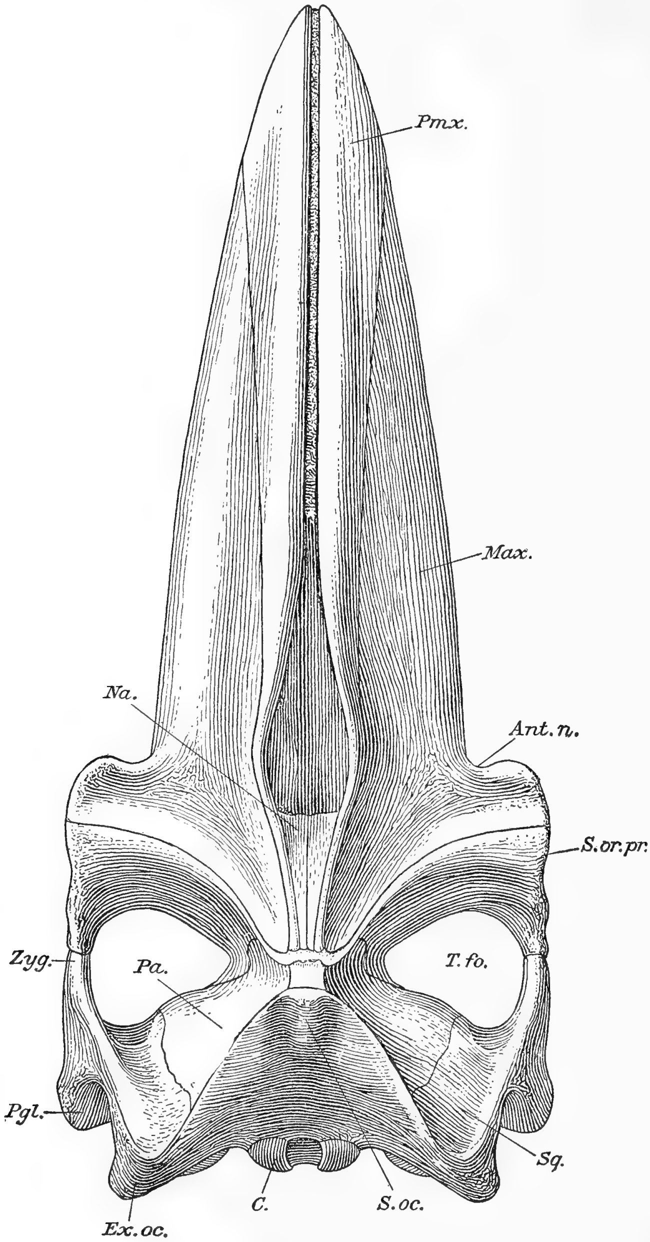

Fig. 1—Dorsal view of skull of *Mixocetus elysius* corrected for distortion, No. 882, Los Angeles Mus. 1/16 nat. size.

Abbreviations: ***Ant.n.***, antorbital notch of maxillary; ***C.***, occipital condyle; ***Ext.a.m.***, channel for external auditory meatus; ***Ex.oc.***, exoccipital; ***f.ov.***, foramen ovale; ***J.n.***, notch for jugular leash; ***L.pr.***, lateral process of basioccipital; ***Max.***, maxillary; ***Na.***, nasal; ***O.c.***, optic canal; ***Pa.***, parietal; ***Pal.***, palatine; ***Per.***, periotic; ***P.gl.***, postglenoid process; ***Pmx.***, premaxillary; ***P.pr.***, posterior process of periotic; ***Pt.***, pterygoid; ***S.oc.***, supraoccipital; ***S.or.pr.***, supraorbital process of frontal; ***Sq.***, squamosal; ***T. fo.***, temporal fossa; ***Zyg.***, zygomatic process of squamosal.

In front of the vomer, each premaxillary curves downward and inward to meet its fellow on the mid-line of the rostrum. The vomer behind and the premaxillaries in front thus contribute the floor and the sides of the dorsal narial gutter.

The premaxillaries attain their maximum width at the level of the anterior ends of the maxillaries. Behind the anterior ends of the maxillaries, there is a quite obvious side-to-side narrowing of the premaxillaries and their internal edges are parallel as far backward as anterior end of the dorsal narial fossa where their inner borders are bent abruptly downward. The narrow ascending or facial process of the premaxillary is lodged in a groove, which follows along the dorso-internal angle of the hinder end of the maxillary, and it terminates at the level of the hinder ends of the nasal bones. In addition to this connection with the maxillary, the slender ascending process of the premaxillary is securely attached to deep grooves in the narial process of the frontal.

On this skull, like on those of *Mesocetus* and *Metopocetus,* the backward thrust of the median portion of the rostrum has carried the ascending processes of the maxillaries and premaxillaries, as well as the nasals, beyond the level of the anteriormost portion of hinder edge of supraorbital process.

The dorsal narial fossa is deep and quite broad, the maximum transverse diameter at a point about 150 mm. in front of the anterior ends of the nasal bones being 170 mm. The maximum antero-posterior diameter of this fossa is approximately 650 mm.

The slender nasal bones are short, equaling about 11.4 per cent of the total length of the skull. The anterior end of each nasal is noticeably thickened dorso-ventrally and is curved from side to side, but is strongly attenuated toward the hinder end. These two nasal bones are wedged in between the ascending processes of the premaxillaries and overhang in front the dorsal narial fossa. Their hinder ends are mortised into the narial process of the combined frontals. No attempt has been made to remove the matrix which fills the narial passages and probably also conceals the turbinated bones, since both nasal bones are crushed downward into the dorsal narial fossa.

The lachrymal is missing on both sides. This element normally is wedged in between the postero-external angle of the maxillary and the preorbital angle of the supraorbital process of the frontal.

The frontals are very narrowly exposed medially and are excluded from the vertex by the parietals. In the interorbital region, the frontals are over-ridden anteriorly by the ascending processes of the maxillaries and of the premaxillaries, as well as by the nasals; and posteriorly they are suturally united with the parietals at the anterior end of the intertemporal constriction. The rostral wall of the cranium is formed largely by the frontals. The supraorbital process of each frontal is curved strongly downward at the base from the level of the dorsal surface of the interorbital region. Each supraorbital process exhibits a prominent transverse arch or temporal crest, anterior to which the dorsal surface slopes forward in a slightly convex curvature, while posteriorly this surface presents a concave downward curvature. The preorbital angle of this process is rounded and the postorbital projection is somewhat elongated.

The parietals, which meet medially to form a very short intertemporal region, are over-ridden posteriorly by the large triangular supraoccipital shield. The ventral edge of each parietal is suturally united with the corresponding squamosal. Antero-laterally each parietal sends forward a thin and narrow process which over-rides the postero-basal portion of the supraorbital process and also partially conceals the fronto-parietal suture. The anterior end of this thin process of the parietal extends forward beyond the level of the hinder end of the ascending process of the maxillary.

The supraoccipital is quite broad at the base and is narrowed toward the rather broad and rounded apex, forming a triangular shield. The forward thrust of the supraoccipital shield has not, however, carried the apex beyond the level of the hinder or parietal margin of the temporal fossa. The lambdoidal crest, which is formed by the contact of the lateral edges of the supraoccipital with the hinder edges of the parietals and squamosals, exhibits a marked tendency to curve outward. This lambdoidal crest was more or less eroded on both sides and has been restored.

From a dorsal view, the occipital condyles appear to be flattened against the posterior end of the basicranium, the exoccipitals are not entirely concealed by a backwardly projecting hinder edge of the squamosal, the squamosals and parietals bulge outward and forward on the lateral wall of the cranium, and the zygomatic processes are quite slender. The presence of a deep re-entrant notch (pl. 1) at the postero-internal angle of each temporal fossa is not difficult to explain. These notches represent fractures that have resulted from the effects of crushing.

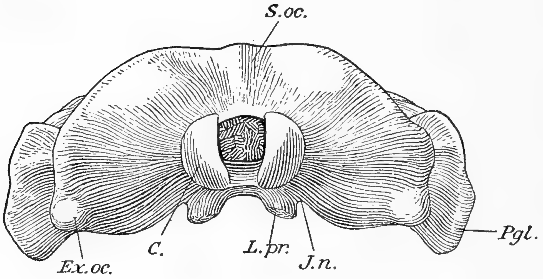

FIG. 2—Posterior view of skull of *Mixocetus elysius* corrected for distortion, No. 882, Los Angeles Mus. 1/16 nat. size. (For explanation of abbreviations, see fig. 1.)

One of the diagnostic features of the cetothere skull is the shape of the temporal fossa. The antero-posterior diameter of this fossa internally as well as the curvature of the hinder margin of the supraorbital process and of the anterior squamosal-parietal margin of the cranium impart a characteristic contour to this portion of the temporal fossa, and in this respect it may have resembled *Metopocetus durinasus*.

Posterior view—The triangular shield, which comprises practically the entire hinder wall of the braincase (fig. 2), is constituted by the medially depressed supraoccipital above and by the large exoccipitals ventro-externally. The lambdoidal crest formed by the lateral margins of the supraoccipital and the abutting hinder edges of the parietals and squamosals curves upward and inward to the rounded apex of this shield. A low and rather short median ridge extends downward from the apex of the supraoccipital shield.

The exoccipitals are unusually large and are thickened antero-posteriorly; their external angles are curved outward and backward. No distinct paroccipital process is developed. The notches for the jugular leash are relatively narrow and the lateral protuberances of the basioccipital do not materially alter the ventral profile.

The occipital condyles are for the most part destroyed (pl. 1), but the fragments preserved indicate that they were considerably broader near the middle than at either end, slightly convex from side to side, and rather strongly convex dorso-ventrally. The right condyle is the best preserved of the two. These condyles are not borne on any visible neck and are not set off from the hinder surface of the exoccipital either by a groove or by a depression.

The rather large postglenoid process projects outward and also downward beyond the level of the outer angle of the exoccipital.

Lateral view—The highest point in the dorsal profile is formed by the apex of the supraoccipital shield, in front of which the dorsal profile of the short intertemporal region passes imperceptibly into the gradual downward and forward slope of the premaxillary.

The rostrum anteriorly is relatively shallow dorso-ventrally, but gradually increases in depth behind the level of the anterior end of the dorsal narial fossa. The outer edge of the maxillary is quite thin throughout its length, but develops a somewhat thicker postero-external angle behind and external to the rather wide antorbital notches. The arched extremity of the supraorbital process of the frontal provides a complete osseous roof for the orbit. The preorbital angle of the supraorbital process is rounded and slightly thickened, but the postorbital angle or projection is somewhat deeper dorso-ventrally and is abruptly truncated behind. The hinder face of the postorbital projection abuts against the obliquely truncated anterior end of the zygomatic process.

The zygomatic process of the squamosal is rather slender, the curvature of the ventral profile being regularly concave from its anterior end to the extremity of its postglenoid process, while the dorsal profile rises gradually posteriorly and merges behind with the outwardly over-rolling lateral crest of the squamosal, which in turn is continuous behind with the short forward projection of the lambdoïdal crest. The postglenoid process swells out behind, forming a rounded protuberance. The squamosal as a whole is rather large, contributing a considerable portion of the lateral wall of the cranium. It is strongly depressed between the hinder portion of the lambdoidal crest and the low lateral crest which is continuous anteriorly with the dorsal margin of the zygomatic process. This low lateral crest overhangs a rather deep elongate concavity on the external face of the squamosal above the postglenoid process.

Each parietal contributes the major portion of the lateral wall of the cranium. They meet behind the frontals to form the short isthmus which connects the occipital portion of the skull with the facial or interorbital portion. The dorsal and posterior edges of the parietal form a continuous curve which is overlain by the lateral edge of the supraoccipital shield, the apex of which projects forward to the level of the anterior squamosal-parietal swelling. The exoccipital is unusually thick and its outer angle projects backward conspicuously beyond the squamosal. The occipital condyles are not visible when the skull is viewed from the side.

Ventral view—The under surface of the cranium (pl. 1) is imperfectly preserved and it is also somewhat crushed. Some of the basicranial elements are badly damaged, but the boundaries of practically all the elements can be recognized, which permits a fairly accurate reconstruction of the ventral surface (fig. 3).

On the ventral side of the skull, the horizontally expanded maxillaries constitute the major portion of the palatal surface. The palatal face of each maxillary is curved from side to side, especially on the proximal portion of the rostrum, and is strongly curved downward internally on the hinder half of the rostrum where it is applied to the under surface of the trough-like vomer. Furthermore, the palatal surface of each maxillary also exhibits a series of shallow curved grooves, those on the hinder region being short and directed obliquely outward, while those on the anterior three-fourths are very long and tend to parallel the longitudinal axis of the rostrum. These vascular grooves supply the ligamentary tissues as well as the blades of baleen which are attached to the roof of the mouth. The thin hinder end of the maxillary is emarginate and is thrust backward below the anterior border of the supraorbital process of the frontal.

The ventral ridge of the trough-like vomer (pl. 1) is visible for its entire length. Distortion, resulting from crushing, has brought about the separation of the inner ventral margins of the maxillaries at a point 400 mm. anterior to the level of the antorbital notches, exposing a greater width of the vomer than is normally visible, and this interval gradually widens toward the anterior extremities of the maxillaries. The trough of the vomer is somewhat wider in front of the antorbital notches than in the interval where normally it is probably entirely concealed by the close approximation of the palatine bones. It is quite possible that the hinder portion of the vomer again makes its ventral appearance at the point where the inner margins of the palatine bones ordinarily commence to diverge from one another. In this region, the vomer develops a 55-mm. high but rather thin carina (maximum transverse diameter at palatal level, 13 mm.) which constitutes the median partition between the internal choanæ. This carina diminishes in height posteriorly and ultimately passes imperceptibly into the short hinder horizontally expanded plate of the vomer. Laterally the vomer is ankylosed with the vaginal process of the corresponding pterygoid.

The hinder ends of both palatine bones are destroyed. The anterior end of each palatine is rounded and fits into a shallow excavation on the under surface of the maxillary. Laterally for a distance of 270 to 280 mm., each palatine is mortised into the internal border of the hinder portion of the corresponding maxillary and also rests upon the trough-like vomer. It also comes in contact with the pterygoid at its postero-external angle. The hinder end of the palatine no doubt projected backward for a short distance below the pterygoid (fig. 3).

The frontals are extended outward, as mentioned previously, to form the expanded supraorbital processes. The right supraorbital process is well preserved. The preorbital angle of the supraorbital process is thickened, but is much less robust than the postorbital projection. The preorbital angle of this process is normally overspread by the lachrymal, a small plate-like element which is wedged in between this angle and the underlying hinder end of the maxillary. The optic canal is bounded in front by a high thick crest and behind by a low thin carina which follows the hinder free edge of the supraorbital process. This canal increases in width from its orifice to beyond the level of the base of the postorbital projection of the supraorbital process. The optic canal is restricted to the hinder third of the ventral surface of the supraorbital process. The rather long postorbital projection of the supraorbital process is quite prominent, rather robust and is curved downward. It is also closely appressed to the extremity of the zygomatic process, but this condition may possibly have resulted from crushing. The anterior border of the under surface of

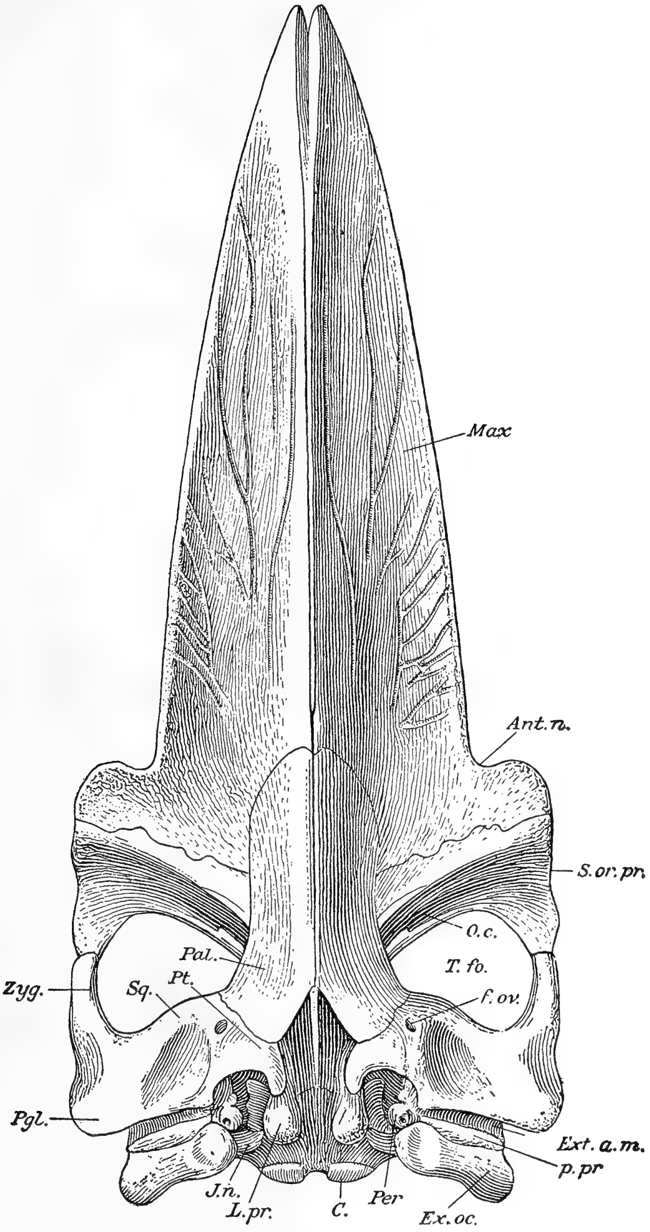

FIG. 3—Ventral view of skull of *Mixocetus elysius* corrected for distortion, No. 882, Los Angeles Mus. 1/16 Nat. size. (For explanation of abbreviations, see fig. 1.)

the supraorbital process is overspread by the thin ventral plate-like process of the maxillary. Unfortunately, the hinder borders of both maxillaries are imperfectly preserved and one can not be certain whether or not these elements projected backward to the level of the channel for the optic nerve.

The jugal is missing on both sides and the absence of any obvious articular surface on the extremity of the zygomatic process would seem to indicate that this element was as loosely connected below the orbit as in recent balænopterids.

The basioccipital is a relatively broad element with its ventral surface strongly concave from side to side. On each side and in front of the occipital condyles is a large lateral descending protuberance which also constitutes the internal wall of the notch for the jugular leash. This lateral protuberance is convex internally and flattened externally. The large occipital condyles do not project backward as far as the level of the postero-external angles of the exoccipitals.

The suture between the basioccipital and the basisphenoid is obliterated, and the level of the hinder margin of the vomer can not be determined with certainty. The ventral surface of the basisphenoid is concealed by the horizontally expanded hinder plate of the vomer and by the vaginal processes of the pterygoids.

The alisphenoid arises from the side of the basisphenoid, projecting upward and outward, and its extremity appears in the temporal fossa on the outer wall of the cranium as a small element which is wedged in between the squamosal, parietal and pterygoid. The ventral surface of the alisphenoid is overspread by the thin plate of the pterygoid, which forms the roof of the oval concavity or fossa for the accessory air sinus of the inner ear. This pterygoid fossa is a characteristic feature of all known mysticete skulls. The pterygoid fossa, as its name implies, is bounded internally by the vaginal process of the pterygoid, anteriorly and antero-externally by the downward curvature of its thickened anterior and outer borders, and postero-externally by the falciform process of the squamosal. Ventrally, this fossa is normally closed over by the hamular process of the pterygoid. The hinder end of this fossa is not closed over by any bony plate or process.

Anterior to the lateral protuberance on the left side of the basioccipital, a remnant of the vaginal process of the pterygoid is attached to the outer margin of the basisphenoid. This process of the pterygoid unfortunately is incomplete on both sides of the median basicranial region. It is also in contact above and internally with the lateral edge of the horizontal plate of the vomer. The hinder end of the vaginal process of the pterygoid rests against the lateral protuberance of the basioccipital. When complete, these pterygoid bones bound the median region of the basicranium and take part in the formation of the lower boundaries of the internal choanæ. In the temporal fossa and on the outer wall of the cranium, the pterygoid is suturally united behind with the squamosal and comes in contact with the frontal anteriorly. On the right side, it is certain that the pterygoid comes in contact with the supraorbital process of the frontal, forming the descending hinder wall of the orifice for the optic canal.

Behind the pterygoid fossa is the large tympano-periotic recess, which is bounded by the squamosal externally, by the lateral protuberance of the basioccipital internally, by the exoccipital posteriorly and by the alisphenoid and underlying pterygoid anteriorly.

The posterior lacerated foramen for the jugular leash occupies the large notch which is located at the postero-internal angle of the tympano-periotic recess. This notch is bounded internally by the lateral protuberance of the basioccipital and externally by the rather poorly defined paroccipital process.

The antero-internal portion of the squamosal is bifurcated to provide the orifice, which constitutes the foramen ovale, for the mandibular branch of the trigeminal nerve. The slender ventral fork or falciform process of the squamosal is suturally united with the pterygoid on the outer wall of the pterygoid fossa. Behind the level of the falciform process there is a distinct indentation on the inner border of the squamosal for lodging the anterior process of the periotic. The anterior margin of the squamosal in the temporal fossa, as seen from a ventral view, bulges forward rather conspicuously, but no re-entrant angle is formed, like in recent balænopterids, where it meets the basal portion of the zygomatic process. Between the level of the foramen ovale and the base of the zygomatic process, there is a large oval concavity (transverse diameter, 155 mm.; antero-posterior diameter, 170 mm.) for lodging the condyle of the mandible. This area is continuous externally with the much narrower and slightly concave glenoid surface on the basal portion of the zygomatic process. The first mentioned area lies at a slightly lower level than the corresponding surface of the basioccipital. The zygomatic process of the squamosal is quite slender, slightly flattened on its external and internal faces, and slightly arched in a fore and aft direction, but not noticeably bowed outward. The postglenoid process is quite robust and is bluntly rounded at its ventral end. The right postglenoid process is incomplete. The left one was broken off during the excavation of the skull and it is quite possible that it has not been correctly attached to the zygomatic process.

Behind this broad and rather robust postglenoid process is a well-marked channel, at least 25 mm. wide, for the external auditory meatus. This channel originates at the postero-internal angle of the squamosal and extends outward almost at right angles to the longitudinal axis of the basicranium. The posterior process of the periotic is wedged in between the posterior face of the squamosal and the thick exoccipital.

The exoccipitals are unusually thick (maximum antero-posterior diameter ventrally, 100 mm.), and curve outward and backward. The outer ends of these bones are deflected rather strongly backward. No distinct paroccipital process is developed.

Measurements of the skull (in millimeters)

Greatest length of skull, anterior end of left premaxillary to level of postero-external angles of exoccipitals	2472
Distance between anterior end of left premaxillary and posterior surface of left occipital condyle	2434
Distance between anterior end of left premaxillary and posterior surface of postglenoid process	2317
Distance between anterior end of left premaxillary and apex of supraoccipital shield	2065
Length of rostrum, level of antorbital notches to anterior end of left premaxillary	1590
Greatest length of left premaxillary	2000
Distance between anterior end of left premaxillary and anterior end of left nasal bone	1725
Distance from apex to supraoccipital shield to posterior end of right nasal bone.	77
Greatest length of right nasal bone	292
Transverse diameter of right nasal bone, anteriorly	57
Transverse diameter of right nasal bone at hinder end	10.5
Combined width of nasal bones, anteriorly	115±
Combined width of nasal bones at hinder ends	22

Transverse distance between outside margins of premaxillaries at level of anterior ends of nasal bones	175
Maximum transverse diameter or left premaxillary at level of anterior end of left maxillary	145±
Transverse diameter of rostrum at level of antorbital notches	660
Transverse diameter of skull across preorbital angles of supraorbital processes	970±
Transverse diameter of skull across postero-external angles of supraorbital processes	990
Greatest antero-posterior diameter of right supraorbital process	337
Transverse diameter of skull between outer surfaces of zygomatic processes	1000
Transverse diameter of skull between outer margins of exoccipitals	785±
Transverse distance between outer margins of occipital condyles	268±
Distance from upper margin of foramen magnum to apex of triangular supraoccipital shield	405±
Vertical distance from basisphenoid to apex of supraoccipital shield	300
Greatest length of left zygomatic process, extremity of postglenoid process to anterior end of zygoma	390
Greatest breadth of basioccipital between inner surfaces of notches for jugular leash	238
Least intertemporal diameter of cranium on ventral face	295
Least intertemporal diameter of cranium on dorsal face	75
Greatest antero-posterior diameter of left palatine bone	540±
Greatest transverse diameter of combined palatine bones, anteriorly	270±
Greatest antero-posterior diameter of left pterygoid fossa	152
Greatest transverse diameter of left pterygoid fossa	77

TYMPANIC BULLA

Both of the tympanic bullæ are so badly crushed and imperfectly fossilized that very little information of diagnostic importance can be obtained from an examination of the fragments preserved. The right bulla is the most complete of the two. The thin outer lip, which arches over the epitympanic recess, is entirely destroyed in front of the level of the sigmoid process, the sigmoid process itself is missing, and the basal portion alone of the posterior pedicle is preserved.

The thick involuted portion of the bulla decreases in width anteriorly. At the level of the sigmoid process, there is a rather broad transverse depression on the dorsal and lateral surfaces of the involucrum. The dorsal and lateral surfaces of the involucrum are relatively smooth, notwithstanding the presence of a number of fine ridges and grooves. The maximum transverse diameter of the involucrum of the left bulla is 43 mm. and its maximum dorso-ventral diameter is 48 mm. The posterior pedicle is attached to the hinder end of the involucrum in the usual position. The anterior or eustachian aperture is relatively narrow. The entire bulla appears to be attenuated anteriorly. The antero-posterior diameter of the right bulla is approximately 102 mm. and the maximum transverse diameter posteriorly is at least 58 mm.

PERIOTIC

Both of the periotics attached to this skull are imperfectly fossilized and are also more or less incomplete. The vestibular and cochlear portions as well as the anterior process of each periotic are crushed into the tympano-periotic recess, and the connection between them and the posterior process is broken off. Hence an adequate description of this element is impossible.

The periotic of this cetothere exhibits the same side-to-side compression of the anterior process as the Belgian *Mesocetus longirostris*,[1] but the posterior process is more elongated. The anterior process of this periotic is transversely expanded at the base, forming an external swelling opposite the fossa for the head of the malleus. The internal or cerebral surface of this process is, however, nearly flat, the anterior extremity is emarginate, and its dorso-ventral diameter is proportionately great (maximum diameter at least 57 mm.).

The tympanic face of the *pars cochlearis* is smaller than the ventro-external basal enlargement of the anterior process and its antero-posterior diameter is apparently greater than its transverse diameter. The tympanic surface of the *pars cochlearis* is convex in a fore and aft direction and its external face rises abruptly from the inner margin of the *fenestra ovalis*.

Bordering upon the external margin of the epitympanic orifice of the *aquœductus Fallopii* is a large shallow concavity for lodging the head of the malleus. This fossa measures 10 mm. transversely and 6 mm. antero-posteriorly. The *fossa incudis* apparently is destroyed on both periotics.

The *fenestra ovalis*, which lodges the foot-plate of the stapes, is rather small and is partially encircled by a narrow elevated rim, which separates it from the channel leading backward from the epitympanic orifice of the Fallopian aqueduct. The facial nerve passes backward in this channel on the tympanic face of the periotic and then turns outward around the hinder face of the basal portion of the posterior process. No obvious carina separates the rather large fossa for the stapedial muscle from this channel for the facial nerve. The hinder face of the *pars cochlearis* is abruptly truncated above the *fenestra rotunda*.

The posterior process is elongated, attenuated at both ends, and relatively narrow. The cerebral face of the periotic could not be examined without serious injury or possible destruction of this element.

Measurements of the left periotic (in millimeters)

Breadth of periotic at level of *fenestra ovalis*, from external face above *hiatus epitympanicus* to internal face of *pars cochlearis*	64+
Greatest length of posterior process, external wall of groove for facial nerve to extremity of process	178
Maximum anterior-posterior diameter of posterior process, exposed surface only.	43
Distance between epitympanic orifice of *aquœductus Fallopii* and tip of anterior process	80
Greatest transverse diameter of anterior process at base, ventral surface	32
Greatest transverse diameter of combined stapedial fossa and hinder end of groove for facial nerve	13
Greatest antero-posterior diameter of *pars cochlearis*	37±

MANDIBLES

Both of the mandibles associated with this skull are imperfectly preserved and are unfortunately crushed flat, obliterating the natural outward curvature of the rami. The right mandible is fractured in thirteen places and lacks the condyle. The left mandible is broken in at least eight places and lacks most of the coronoid process. In general proportions, these mandibles seem to agree with those of *Aglaocetus moreni* (Lydekker) (Cat.

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[1] P. J. van Beneden, *Description des ossements fossiles des environs d'Anvers. Pt. 5. Genres: Amphicetus, Heterocetus, Mesocetus, Idiocetus and Isocetus*, Ann. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, vol. 13, pl. 36, figs. 4-5, 1886.

No. P. 13407, Field Museum of Natural History). The vertical diameter of the horizontal ramus is approximately the same as that of *Cetotherium cephalum* Cope (Cat. No. 11976, U. S. Nat. Mus.).

At the anterior extremity. the right mandible measures 135 mm. in depth. The internal surface of each mandible is distinctly flattened, especially so on the proximal portion, but becomes slightly convex near the distal end. The symphysis is very short and its longest diameter does not exceed 80 mm. The symphyseal area has a number of large, deep and rather smooth pits for the attachment of the symphyseal ligaments, but it is nowhere rugose. The convex curvature of the external face of the mandible is quite pronounced and the maximum transverse diameter is above the level of the center of the horizontal ramus. The inferior face of the middle portion of the horizontal ramus is unusually broad and almost flat, and on the right mandible attains a maximum width of 103 mm. at a point 1440 mm. behind anterior end, but superiorly the ramus is abruptly narrowed to form a thin longitudinal ridge. These mandibles in their original condition were undoubtedly bowed outward on at least their hinder one-third, since the maximum length of the left mandible is greater than the distance from the glenoid cavity to the extremity of the premaxillary. Viewed from the side, the inferior margin of the mandible exhibits a slight concave curvature.

The internal foramina are quite small and are situated about an inch apart, forming a longitudinal alveolar series in the groove which follows the upper edge of the mandible. The external series of mental foramina are rather large and are separated by intervals varying from 75 to 150 mm. They are also placed at a lower level than the internal foraminal series and tend to drop down to a still lower level near the anterior extremity. Each of these external foramina opens into a groove which leads forward, the anteriormost foramen having a groove fully five times as long as the hindermost one. The external foraminal series terminates 330 mm. behind the anterior end of the right mandible and 340 mm. behind the anterior end of the left mandible.

The coronoid process is a low outwardly curved plate, subtriangular in outline, and with apex above internal orifice for the large mandibular canal. The anterior margin of the low coronoid process rises rather gradually, but its hinder margin descends abruptly.

The condyle is quite large, rather strongly compressed from side to side, and is transversely convex above and below. Above the center, the internal border of the condyle is strongly indented, forming a broad groove. The dorso-internal angle of the condyle is rather noticeably flattened. The maximum transverse diameter (96 mm.) is slightly below the center of the condyle. No distinct angle is developed.

Measurements of mandibles (in millimeters)

	Left	Right
Greatest length of mandible in a straight line (crushed flat)	2335	×
Greatest vertical diameter of mandible at symphysis	135	136
Greatest transverse diameter of mandible at symphysis	60.5	66
Greatest vertical diameter of mandible at coronoid process	×	255
Greatest vertical diameter of mandible at a point 400 mm. in front of posterior face of condyle	195	×
Greatest vertical diameter of mandible at a point 840 mm. in front of posterior face of condyle	175	×
Greatest transverse diameter of mandible at a point 1440 mm. behind anterior extremity of mandible	×	103
Greatest vertical diameter of condyle	215	×
Greatest transverse diameter of condyle	96	×

VERTEBRÆ

Assuming that the vertebral column consisted of 7 cervicals, 12 dorsals, 12 lumbars and 14 caudals, and computing the lengths of the centra of the missing vertebræ from the relative lengths of those that were found, the total length of the skeleton, including the skull, approximated 32 feet or 9.75 meters.

CERVICAL VERTEBRÆ

A block of laminated shale containing the third to the seventh cervicals, inclusive, as well as the first and second dorsals, all in natural sequence, was taken up about two feet behind the skull. The centra of these vertebræ are crushed against one another, forming a rather compact mass. The atlas and axis of this specimen were not found and remainder of the cervical vertebræ are imperfectly preserved. The neural arches of the third to seventh cervicals, inclusive, with the exception of the basal portions of their pedicles, are completely destroyed. The centra increase in antero-posterior diameter from the third to the seventh.

Although the transverse processes of both the third and fourth cervicals are broken off, a basal fragment of the right lower process is preserved on the last-mentioned vertebra. On the basis of this remnant one might infer that the lower process is quite similar to the same process on the fifth cervical.

The fifth cervical has a long, slender, dorso-ventrally flattened lower transverse process (measuring 45 mm. antero-posteriorly and 15 mm. dorso-ventrally at the extremity), which projects outward about 100 mm. from the lateral surface of the centrum. The upper transverse process is somewhat heavier and not quite so long; no indication of any osseous isthmus between the outer ends of the upper and lower transverse processes is present, although it is quite obvious that the interval separating these two bars is much less distally than at their bases.

On the left side, the outer one-third of the centra, as well as the transverse processes which arise from this side, of the sixth and seventh cervicals are ankylosed together. On the right side these two hinder cervicals appear to be normal and have the usual processes. This anomalous condition may have resulted from some embryologyical disturbance. The centra of the sixth and seventh cervicals are strongly compressed antero-posteriorly, but are relatively broad. The transverse processes of these two hinder cervicals consist of a robust lower bar and a rather thin upper bar, which may or may not be united by a bony isthmus at their extremities to form a complete osseous frame for the arterial canal. The centra of the preceding vertebra are, however, free.

Measurements of cervical vertebræ (in millimeters)

Maximum antero-posterior diameter of centrum of third cervical	48.5
Maximum antero-posterior diameter of centrum of fourth cervical	49.
Maximum antero-posterior diameter of centrum of fifth cervical	49.5
Maximum antero-posterior diameter of centrum of sixth cervical	53.5
Maximum antero-posterior diameter of centrum of seventh cervical	63.

DORSAL VERTEBRÆ

Since the transition between the hinder dorsals and the anterior lumbars is rather gradual in most mysticetes, it is practically impossible to determine the precise number of vertebræ in the dorsal series, unless the ends of the transverse processes are preserved. The ends of these processes are, unfortunately, destroyed on the hindermost vertebræ. It is known, however, that at least some of the Miocene cetotheres have a dorsal series consisting of twelve vertebræ and it is therefore tentatively assumed that this cetothere has a like number of dorsal vertebræ. The epiphyses of all the vertebræ allocated to the dorsal series are fully ossified and are completely coalesced with the centrum. All of the dorsal vertebræ, with the exception of one anterior and four of the hinder ones, lack practically all of their processes, including not only the diapophyses and parapophyses, but the neural arch and the neural spine as well.

The centra of the first to twelfth dorsals progressively increase in length, the hindermost one having a centrum more than twice the length of the anteriormost one. The centrum of the sixth dorsal, however, is considerably longer than that of the fifth in this series.

The first dorsal resembles the hindermost cervical more closely than do the succeeding dorsal vertebræ, the proportions of the centrum being somewhat similar, but it is recognizable at once by the presence of a diapophysis projecting forward and outward. At the extremity of this robust diapophysis, there is a large articular facet for the tuberculum of the corresponding rib.

The centrum of the fourth dorsal is almost hemi-cylindrical in shape, its transverse diameter being much greater than its vertical diameter. Although the robust pedicles of the neural arches are broken off at the base, it is obvious that their transverse and longitudinal diameters are about equal, and that they are placed much nearer the anterior than the posterior end of the centrum. It is quite obvious that the diapophysis is supported on the external face of the neural arch by a buttress which extends downward to the base of the pedicle. The transverse diameter of the neural canal at the base is at least 81 mm. At the antero-superior angle, and also at the postero-superior angle, of the lateral face of the centrum, there is a small facet for articulation with the capitulum of the corresponding rib.

On the seventh in the dorsal series, the transverse process (parapophysis) arises from the side of the centrum slightly below the level of the base of the corresponding pedicle of the neural arch. The antero-basal angle of each transverse process is almost flush with the anterior face of the centrum, while the postero-basal angle is at least 42 mm. distant from the hinder face. The lateral faces of the centrum are strongly contracted below the level of these processes and between the epiphyses. The maximum transverse diameter of the centrum is approximately at the level of these processes. The pedicles of the neural arch are rather thin transversely and are set back at base at least 40 mm. from the hinder face of the centrum, while the anterior edge of the pedicle is almost flush with the anterior face of the centrum. The transverse diameter of the neural canal at the base does not exceed 63 mm.

The neural canal of the eighth dorsal is somewhat narrower and the pedicles of the neural arches are rather thin transversely, but are elongated antero-posteriorly. The neural arch is crushed laterally and the neural spine is destroyed. On this vertebra, the transverse processes arise from almost the center of the lateral face of the centrum. At the base, the transverse processes extend almost the full length of the centrum.

With the exception of its slightly larger dimensions, the ninth dorsal is quite similar to the eighth in this series. The neural spine and the neural arch are badly crushed and are also partially destroyed. It is apparent, however, that the neural spine is quite broad antero-posteriorly at the base and that it rakes somewhat backward.

The tenth and eleventh dorsals have slightly longer centra than the preceding. Their transverse processes are relatively broad at the base, the pedicles of the neural arches are thin and elongated antero-posteriorly, and the neural spines are large and wide at the base.

Broad transverse processes arise from near the center of the lateral face of the centrum of the twelfth dorsal and at the base are almost equally distant from the anterior and posterior faces of the centrum. Transverse processes of similar dimensions and occupying the same position were undoubtedly present on the first and second lumbars. The centrum, viewed either from in front or from behind, is distinctly more oval in outline than near the middle of the dorsal series. The pedicles of the neural arch are quite thin transversely and are rather long antero-posteriorly.

Measurements of dorsal vertebræ (in millimeters)

	1st	2d	3d	4th	5th	6th	7th	8th	9th	10th	11th	12th
Maximum antero-posterior diameter of centrum	75	84	88.5	113	108	134	142	156	162	180[1]	170	177
Maximum transverse diameter of anterior face of centrum	...	...	...	173.5	...	...	185	174	...	...	...	182.5
Maximum vertical diameter of anterior face of centrum	...	...	...	123	...	...	130	136.5	...	...	...	140
Maximum transverse diameter of posterior face of centrum	210±	...	...	176	...	...	...	184	...	...	...	190
Maximum vertical diameter of posterior face of centrum	123	...	...	127	...	...	...	139	...	...	...	148

[1] Crushed.

LUMBAR VERTEBRÆ

The lumbars resemble the posterior dorsals in general configuration and are characterized in part by the absence of rib-bearing facets at the extremities of the transverse processes. Five vertebræ, found in natural sequence are tentatively allocated to the lumbar series. The neural arches, with the exception of the basal portions of their pedicles, the neural spines and the transverse processes are destroyed on all of these vertebræ. The third, fourth and fifth lumbars are so badly damaged that it is impossible to obtain any accurate data on their structural peculiarities. In case of the anterior lumbars, it is certain that no median longitudinal carina is developed on the inferior surface of the centrum, but on the fifth in this series, however, there is an obvious tendency toward the lateral contraction of the centrum and a corresponding pinching in of the ventral surface in a longitudinal direction. This condition may indicate the existence of a distinct carina on the hindermost vertebræ in the lumbar series. It is obvious, however, that the centra of these lumbars increase in length from the first to the fifth in the series.

Maximum antero-posterior diameter of centrum of first lumbar	174 mm.
Maximum antero-posterior diameter of centrum of second lumbar	190 mm.

SCAPULA

As regards its general dimensions, the left scapula of the Modelo cetothere is considerably larger than that of *Cetotherium cephalum* Cope (Cat.

No. 11976, U. S. Nat. Mus). The internal surface of this scapula is essentially flat. The vertebral margin is regularly convex in contrast to the usual flattening which characterizes the central portion of this border in most of the living species of *Balænoptera.* The unusual breadth of this scapula is probably its most obvious peculiarity.

The acromion is well developed, rather broad (115 mm. at base and at least 60 mm. at broken extremity), and is directed forward and slightly downward. The rather short and attenuated slender coracoid process arises from the anterior end of the articular head of the scapula and is directed forward and obliquely outward. The short neck of this scapula is quite broad, and the articular cavity for the reception of the head of the humerus is unusually large. Above the acromion, the anterior margin of the scapula is curved forward and meets the vertebral margin in a rounded acute angle. The hinder margin of this scapula is much longer than the anterior margin and exhibits a regular concave curvature.

In area, the prescapular fossa is quite small and the postscapular fossa is unusually large.

Measurements of left scapula (in millimeters)

Greatest vertical diameter, articular head to vertebral margin	455
Greatest antero-posterior diameter	775
Length of acromion, superior margin at base to distal end of process	115+
Dorso-ventral diameter of acromion at broken distal end	58
Antero-posterior diameter of articular head	215

REMARKS

When the skull is viewed from above, the curvature of the anterior and posterior margins of the temporal fossa, the depression of the dorsal surface of the squamosal behind the base of the zygomatic process, the extent of the forward thrust of the supraoccipital shield, the acute angle at which the short external portion of the lambdoidal crest is deflected forward, the shortness of the intertemporal region, and the conspicuous backward thrust of the median rostral elements form a combination of characters which finds its closest counterpart in *Mesocetus longirostris* and *Metopocetus durinasus.*

As regards the interdigitation of the rostral and cranial portions of the skull, the Upper Miocene *Mesocetus longirostris*[1] seems to represent a slightly more advanced stage than the Modelo cetothere. The squamosal and the exoccipital portions of the type skull of *M. longirostris* (Cat. No. 39, Musée royal d'histoire naturelle de Belgique) are now separated from each other and also from the dorsal cranial fragment. The upper portion of the supraoccipital shield of the Belgian cetothere is somewhat smaller than that of the Modelo cetothere, as is shown by the following measurements: Distance from apex of supraoccipital shield to ventral angle of lambdoidal crest, as

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[1] P. J. van Beneden, *Description des ossements fossiles des environs d'Anvers. Pt. 5. Genres: Amphicetus, Heterocetus, Mesocetus, Idiocetus and Isocetus,* Ann. Mus. Roy. d'Hist. Nat. de Belgique, Bruxelles, vol. 13, pls. 34-35, 1886.

preserved, 430 mm.; transverse distance between ventral angles of opposite portions of lambdoidal crest, 440 mm. The essential structural features of the skull of *Mesocetus longirostris* may be described briefly as follows: Backward thrust of rostrum seemingly has carried the hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries and the nasals) beyond level of anteriormost portion of hinder edge of supraorbital process of frontal; apex of supraoccipital shield thrust forward, reducing length of contact of opposite parietals on intertemporal constriction; a narrow sagittal crest developed on a relatively short intertemporal constriction; anterior temporal crest on supraorbital process of frontal thin, rather sharp-edged, and abruptly elevated at base above anterior process of parietal; thin anterior process of parietal, which overrides basal portion of supraorbital process, extended forward beyond level of hinder ends of median rostral elements (ascending processes of maxillaries and of premaxillaries, and the nasals); exposure of frontals in median interorbital region reduced to a quite small strip, very narrow antero-posteriorly; ascending process of maxillary extremely narrow, but wider than nasal; width of ascending process of premaxillary greater than combined width of nasal and ascending process of maxillary; and the exoccipitals are somewhat thickened.

The much smaller Upper Miocene *Metopocetus durinasus*,[1] which was presumably derived from the Calvert formation, represents a more advanced stage in the interdigitation of rostral and occipital elements, for the hinder ends of the ascending processes of the maxillaries are almost in contact with the apex of the supraoccipital shield, the interval between them being 19.5 mm. The intertemporal constriction is therefore quite short and is strongly pinched in. Furthermore, the ascending process of each maxillary is fused with the ascending process of the corresponding premaxillary, the nasals are noticeably wider anteriorly than those of *Mesocetus longirostris* and the supraoccipital shield is more conspicuously narrowed toward the apex. On the type skull of *Metopocetus durinasus* (Cat. No. 8518, U. S. N. M.), the thin anterior process of the parietal, which overrides the basal portion of the supraorbital process, is likewise extended forward beyond the level of the hinder ends of the median rostral elements, the exoccipital is somewhat thickened antero-posteriorly, the anterior temporal crest on the supraorbital process is hidden by the overspreading ascending process of the maxillary,

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[1] E. D. Cope, *Sixth contribution to the knowledge of the marine Miocene fauna of North America*, Proc. Amer. Philos. Soc., vol. 35, No. 151, 141, pl. 11, fig. 3. Aug. 15, 1896.

and the backward thrust of the median rostral elements has entirely concealed the frontals in the median interorbital region.

The skull of the Modelo cetothere (pl. 1) resembles in a general way that of "*Aulocetus*" *sammarinensis*[1] from the Helvetian calcareous limestone of Mount Titano in San Marino, Italy, but is considerably larger. The San Marino cetothere skull is distinguished readily from the Modelo skull by having the nasals extended forward beyond the level of the preorbital angles of the supraorbital processes, a narrow sagittal crest on the intertemporal constriction, a rostrum relatively broad at base and strongly attenuated toward disal extremity, and relatively slender postglenoid processes. Furthermore, the exoccipitals of the San Marino skull are not unusually thickened anteroposteriorly, the rounded and quite broad supraoccipital shield is not thrust forward as far as that of the Modelo skull, and the anterior temporal crests on the supraorbital process are rather indistinct and not abruptly raised above the level of the thin anterior process of the parietal which overrides the basal portion of the supraorbital process.

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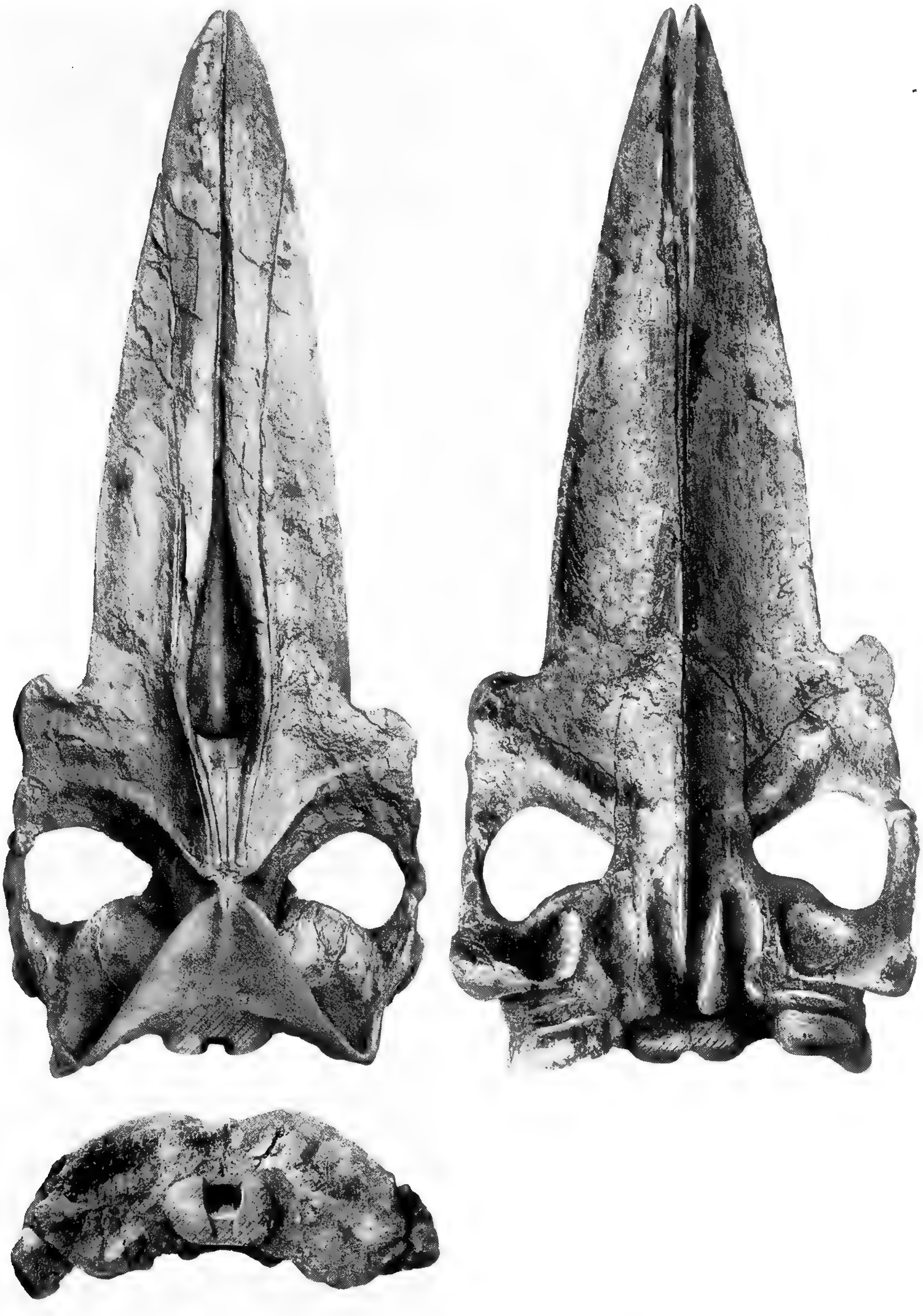
[1] G. Capellini, *Balenotera miocenica del Monte Titano, Repubblica di S. Marino,* Mém. R. Accad. Sci. Ist. di Bologna (5), vol. 9, 246, pls. 1-2, 1901.



A. Dorsal view of skull of *Mixocetus elysius,* No. 882, Los Angeles Mus. 1/17 nat. size.
B. Ventral view of skull of *Mixocetus elysius,* No. 882, Los Angeles Mus. 1/17 nat. size.
C. Posterior view of skull of *Mixocetus elysius,* No. 882, Los Angeles Mus. 1/17 nat. size.

CONTRIBUTIONS TO PALÆONTOLOGY

IV

ANATOMICAL NOTES ON PINNIPEDIA AND CETACEA

By Ernst Huber

With twelve text-figures

[Issued January 20, 1934]

CONTENTS

Among the manuscripts and notes left by the late Ernst Huber was considerable material on the anatomy of pinnipeds and cetaceans. This consisted of a remarkably extensive series of drawings, several addresses which he had given on the subject, incomplete articles and notes in shorthand. No attempt was made to utilize the last, but the addresses were rearranged to avoid repetition, the articles combined, and the most pertinent of the drawings, mostly in pencil, were kindly completed by James F. Didusch. The text concerning the Phocidæ refers almost exclusively to *Phoca hispida;* his notes on *Phoca groenlandica* were not in a condition to be readily utilized. Huber had as yet made no attempt to review the literature on the subject, as he would have done had he lived, and I have made no such additions. I have, however, prepared an introduction embodying explanation of his material. The whole is offered as a series of short chapters, really a digest of his work on the subject, without elaboration. Although incomplete in some respects, it is considered to be far too valuable a contribution to remain unpublished—A. Brazier Howell.

ANATOMICAL NOTES ON PINNIPEDIA AND CETACEA

INTRODUCTION

In the author's program of the investigation of the facial musculature of vertebrates he has, as opportunity offered, investigated a number of forms of the mammalian orders Pinnipedia and Cetacea. Representing the former, I have had opportunity to dissect a California sea-lion (*Zalophus californianus*) that died in the Baltimore zoo, a female specimen of *Phoca hispida* taken by H. C. Raven, Ponds Inlet, Baffin Island, and one of *Phoca groenlandica* secured by the Byrd Arctic Expedition. Of the Odontoceti I have investigated a large fetus of the narwhal, *Monodon monoceros,* secured by H. C. Raven on the American Museum of Natural History Greenland Expedition of 1926, organized and led by G. P. Putnam; a preserved fetus of *Tursiops truncatus* obtained by Remington Kellogg, and fresh adults and a juvenile of the same species at Cape Hatteras. I have also had opportunity to make some investigation on fetuses of *Globiocephala* kindly loaned by the United States National Museum.

PINNIPEDIA

In the pinnipeds, striking modifications have taken place in the facial muscles connected with the outer ear and the snout. Of great importance to these aquatic mammals, of course, was the development of a mechanism to enable them to keep the ear tube closed while submerged, so that the animal upon emergence would be ready to detect air-borne sounds. Of even greater importance to them was the development of a muscle mechanism which would enable them to keep their nostrils tightly closed while beneath the surface.

OTARIDÆ

Representing this family, *Zalophus californianus,* the California sea-lion, was chosen for study. Figure 1A shows how in the nuchal region a layer of transverse muscle bundles arises from the middorsal line. This muscle layer may be interpreted as the persisting dorsal section of the primitive sphincter colli. That this layer must have had a greater ventral expansion in the ancestral plan is indicated by the fact that it continues for a short distance ventralward over the side of the neck, as a degenerate, tendinous plate.

Caudalward the sphincter colli primitivus becomes continuous with the panniculus carnosus. The connection between the two is, of course, secondary, but is so complete that recourse must be had to the innervation to demonstrate their phylogenetic dissimilarity.

The Platysma and Postauriculo-Occipital Muscle Group

From the most cranial portion of the sphincter colli primitivus there deviate oralward those bundles that constitute the deep, nuchal portion of the platysma. This is joined, behind the ear, by the superficial layer of the platysma, which is anchored by its most caudal bundles in the subcutaneous tissue of the side of the neck. The platysma then passes as a continuous, longitudinal layer over the

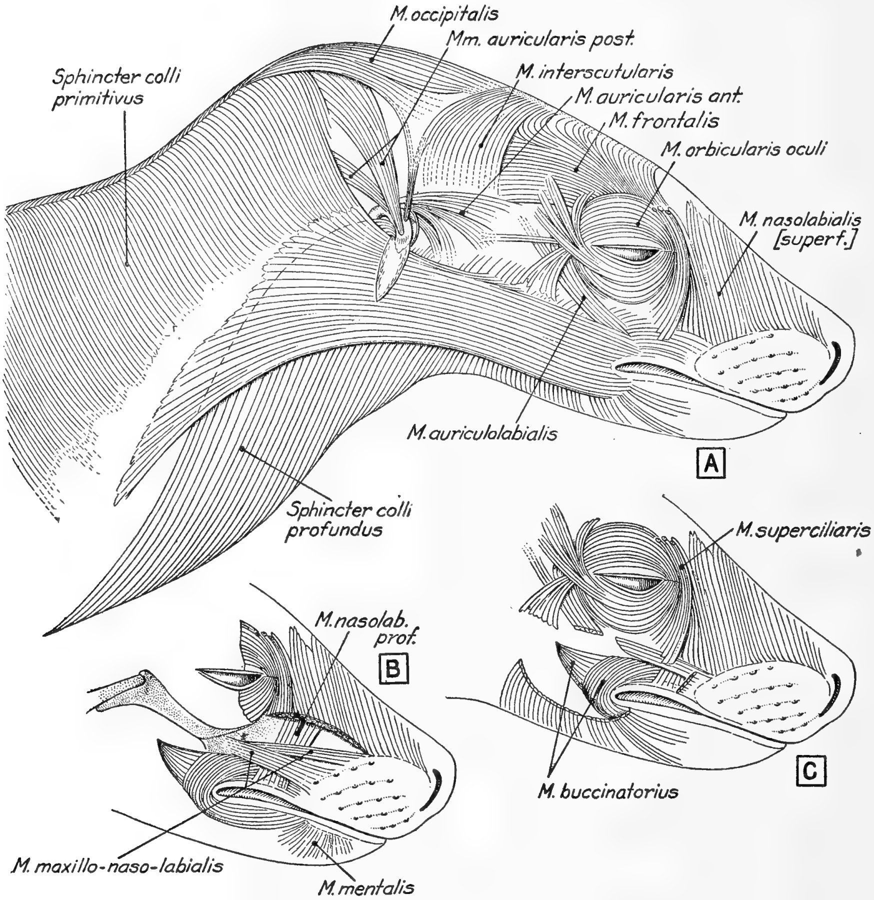


Fig. 1—Facial musculature of *Zalophus californianus.* A, superficial details; B and C, successively deeper details.

lateral side of the head oralward to become inserted into the immediate vicinity of the mouth.

In the occipital region (fig. 1A) in close connection with the deep, nuchal portion of the platysma, arise those muscles which constitute the postauriculo-occipital muscle group. There is a distinct occipital portion which is joined in the middorsal line by the corresponding part of the opposite side to form the unpaired m. occipitalis. This rather large muscle covers the occiput. Anteriorly a small, vestigial, tendinous slip of the muscle deviates ventralward, and joined by a similar slip of the m. interscutularis it inserts into the minute pinna of the outer ear. In addition there are two larger, well-defined mm. auriculares posteriores which reach the pinna from different directions, the larger one overlapping the smaller one. At their insertion into the posterior surface of the pinna they are some distance apart. A distal muscle portion derived from these extrinsic postauricular muscles has settled down on the convex surface of the pinna, thus forming the intrinsic mm. obliqui et transversi. At the caudal and cranial edges of the pinna, marginal bundles of the larger of the mm. obliqui et transversi have migrated to the anterior concave surface of the pinna, thus forming the m. antitragicus and the m. helicis (minor). From the latter, the m. mandibulo-auricularis has evolved. But while the mm. obliqui et transversi, once of functional importance, appear now in the sea-lion as mere vestiges on the greatly reduced pinna, the m. antitragicus, m. helicis and m. mandibulo-auricularis have become strongly developed and modified, being now of great functional importance in connection with the closure mechanism of the outer ear.

The Sphincter Colli Profundus and its Derivatives

Immediately subjacent to the m. platysma there is the sphincter colli profundus. It forms a vast, coherent, transverse muscle layer, which covers the side of the neck and face and extends, as in the primitive ground-plan, as far as the mouth.

Pars Auris

The most caudal portion of the sphincter colli profundus, the pars auris, inserts as a rather broad muscle band into the lower border of the pinna.

Derivatives of the Pars Preauricularis

The preauricular muscle group is represented by several well-developed muscle slips which insert above into the outer ear, while below they have lost connection with their matrix, the pars preauricularis of the sphincter colli profundus. Instead they have settled down in the temporal region. Moreover, the m. auriculolabialis (zygomaticus), which in the primitive ground plan passes from the ear below the orbit to the mouth, has become fully independent of the preauricular muscle complex, although it has retained its primitive connection with the infraorbital portion of the m. orbicularis oculi. It is represented by a feeble muscle vestige which ends on the upper lip near the mouth. At its insertion it is covered by the upper border of the inserting platysma. The m. orbicularis oculi forms a powerful, muscular disk around the eye, with several deviating slips at the lateral angle of the orbit.

Over the frontal region occur two closely adjacent muscles, which require separate description: The first, the homologue of the m. interscutularis of the fissiped carnivores, is a broad, rather thin muscle plate, which crosses the cranial vault anterior to the m. occipitalis. It is an unpaired structure formed by complete fusion of two bilateral components. Laterally in the temporal region this unpaired muscle gradually changes into a tendinous extension, while its most caudal bundles, likewise reduced to tendon, insert as a narrow band into the pinna jointly with the deviating slip of the m. occipitalis described above.

The second muscle of the frontal group is the powerfully developed m. frontalis, which arises under cover of the m. orbicularis oculi from a well-marked process of the supraorbital margin. From there the bundles extend caudalward into the temporal region (orbito-temporal portion) and upward over the flattened forehead (orbito-frontal portion). The bundles of the latter deviate toward the middorsal line where they continue without interruption into the corresponding muscle of the opposite side, while the orbito-temporal part of the m. frontalis posteriorly, dips under the m. interscutularis. Although in the sea-lion, in contrast to the fissiped carnivores, the preauricular section of the frontal muscle complex has to a large extent deteriorated, the author could by careful dissection demonstrate a persistent, fine, tendinous platelet which, although functionless, still inserts into the minute pinna.

In close genetic relationship with the m. frontalis we find the m. nasolabialis (fig. 1A) which, as a thick, very powerful muscle, covers the lateral surface of the snout. It inserts below into the tough cushion of connective tissue in which the long, mystacial bristles are implanted. At the supraorbital ridge, where the m. frontalis has origin, there are a few bundles of the m. nasolabialis linking the two muscles together. In this animal the m. nasolabialis may indeed be considered to be the most distal section of an originally continuous auriculo-temporo-fronto-nasal muscle tract, which has become differentiated into part of the preauricular muscle, m. frontalis and m. nasolabialis. The pinnipeds evidently have adopted this arrangement from the ancestral fissiped ground-plan. The few vestigial muscle bundles connecting the m. nasolabialis with the m. frontalis, as pointed out above, are the last indications in the sea-lion of an originally broader connection. Should this remnant eventually disappear in the course of further phylogenetic development, the m. nasolabialis would remain characteristically innervated by terminal supraorbital branches of the n. facialis, and this would still clearly tell the story of its evolution.

It may not be out of place to mention here that in certain other orders of placentals, including the Primates, the auriculo-temporo-frontal muscle tract does not expand over the snout. The m. nasolabialis of those mammals, although in topography, form and function closely resembling the m. nasolabialis of the fissiped and pinniped carnivores, in the Primates is derived from the infraorbital portion of the m. orbicularis oculi. This is indicated in these forms by the characteristic innervation of the m. nasolabialis through terminal infraorbital branches of the n. facialis. The m. nasolabialis of the Primates is therefore not strictly homologous to the m. nasolabialis of the fissiped carnivores and pinnipeds. This is but one of the many instances which prove that it is necessary to establish the exact nerve-supply in an endeavor to homologize the various muscle complexes and individual muscles of the facial group within the representatives of the various orders of mammals.

The muscle bundles intermediate between the m. orbicularis oculi and the m. nasolabialis of the sea-lion constitute the m. supraciliaris, ending above in the supraciliary region, where it is attached to the bulbs of the supraciliary, tactile vibrissæ, inconspicuous and few in number.

Pars Palpebralis

The muscle bundles corresponding in the sea-lion to the pars palpebralis sphincter colli profundi are not clearly set off from those of the pars preauricularis or pars oris. They are simply intermediate between these portions without having definite relationship to the lower eyelid. In this animal they are evidently not called upon to act as a m. depressor palpebræ inferioris as in certain other mammalian types.

Derivatives of the Pars Oris

These muscles (m. orbicularis oris, m. buccinatorius, m. maxillo-nasolabialis, m. mentalis and m. nasalis) are represented in figures 1B and 1C. In figure 1B the m. orbicularis oculi and m. nasolabialis are left in place simply to show their topographic relationship to the derivatives of the pars oris. Through partial removal of the pars oris in figure IC the m. buccinatorius and part of the labial portion of the m. maxillonasolabialis are exposed. The m. buccinatorius exhibits a simple arrangement. It is situated immediately subjacent to the pars oris sphincter colli profundi from which it is clearly separated. It consists of a superficial and a deep portion. The well-developed superficial part encircles the mouth and extends forward into both the upper and the lower lips, while the deep part of the buccinator, being closely adherent to the mucous membrane of the cheek wall, adopts a longitudinal course. Anteriorly its bundles insert, under cover of the superficial portion, into both upper and lower lips (not shown in figure).

The m. maxillonasolabialis is shown in figure 1B. This muscle arises from the maxilla, just behind the infraorbital foramen. Already at origin it is split into two well-defined portions, the stronger, broader, superficial pars labialis, inserting anteriorly into the mystacial pad close to the border of the upper lip, and the deep, more slender pars nasalis extending toward the snout. With tendinous bundles which penetrate the mystacial pad, the latter ends in the vicinity of the nostril. To the two portions of the m. maxillonasolabialis the m. nasolabialis has definite topographic relationship. The latter dips between the two parts of the m. maxillonasolabialis, covering the pars nasalis of the latter, to become inserted below into the heavy mystacial pad and the adjacent part of the upper lip under cover of the pars labialis of the m. maxillonasolabialis. A weak, deep portion of the m. nasolabialis crosses beneath both parts of the m. maxillonasolabialis to become inserted below upon the border of the upper lip.

In figure 1B the m. mentalis is shown arising from the alveolar border of the mandible in close primitive connection with the portion of the m. buccinatorius to the lower lip. From there its fibers radiate through the subcutaneous tissue over the chin to become inserted into the skin and to the hair bulbs of the vestigial mental vibrissæ.

PHOCIDÆ

I have had opportunity to investigate two representatives of this group, namely *Phoca groenlandica* and *Phoca hispida.* [The text, however, is based almost exclusively on the latter species—A. B. H.] Although there exist marked differences in functional adaptation of the ear musculature in the two species, the general arrangement of their facial musculature exhibits a common plan. But, while the facial musculature in the sea-lion (*Zalophus*) and the seal (*Phoca*) both plainly show the carnivore ground-plan, the two types differ widely in fundamental points, a fact which strongly supports the view that the eared (Otaridæ) and earless seals (Phocidæ) have evolved from two distinct stocks of terrestrial carnivores.

In figure 2 is shown the well-developed transverse muscle layer of the sphincter colli primitivus of *Phoca hispida,* directly continuous with the most cranial section of the panniculus carnosus. This extends considerably farther ventralward on the side of the neck than in the sea-lion.

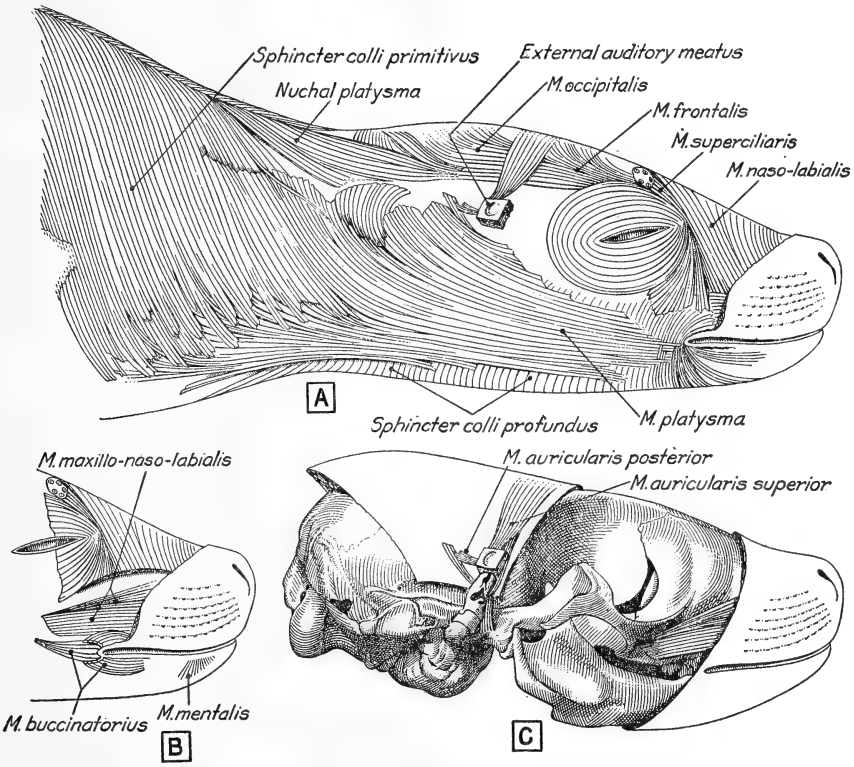


FIG. 2—Facial musculature of ***Phoca hispida.*** A, superficial details; B, deeper details of the snout; C, skull showing position and details of the extracranial parts of the auditory apparatus.

THE PLATYSMA AND THE POSTAURICULO-OCCIPITAL MUSCLE GROUP

The more cranial bundles of the sphincter colli primitivus layer may, as in the sea-lion, be considered as deep portions of the nuchal platysma. They are joined by a superficial, more extensive sheet to form the m. platysma colli et faciei, which passes as a rather broad, longitudinal muscle plate below the ear oralward over the lateral surface of the head to insert in the vicinity of the mouth. At its caudal end the platysma shows an intricate relationship to the sphincter colli primitivus. Part of the platysma bundles there interlace with the most ventral bundles of the sphincter colli primitivus, while others emerge from this primitive layer. This significant fact indicates that in phylogenetic development the superficial sheet of the m. platysma must have split off from the sphincter colli primitivus. In *Phoca* it evidently has not yet become fully segregated from its matrix layer, a very primitive feature which the seals must have retained from the ground-plan of their terrestrial ancestors. In this regard the seal has not progressed as far as the sea-lion and those modern terrestrial carnivores which have so far been investigated. A comparison of figure 1 with figure 2 shows that in the sea-lion the caudal section of the superficial sheet of the m. platysma has become fully independent of its matrix, through reduction of the sphincter colli primitivus in its ventral part, and is now anchored in the subcutaneous tissue of the lateral surface of the neck. In the nuchal region, however, the m. platysma has remained, through its deep nuchal portion, in primitive connection with the sphincter colli primitivus. Thus, while the sea-lion (*Zalophus*) in some respects has progressed farther than the seal (*Phoca*), the rest of the facial musculature of the latter shows modifications in which it far exceeds the sea-lion. This is most striking in those muscles which once had or still have relations with the outer ear.

Whereas in the sea-lion (eared seal) there is a small though well-defined pinna, in the seal (earless seal) there is no pinna present; only the orifice to the lumen, closed on one side by a small, rounded plug and supported by vestigial ear cartilage.

Several small, well-defined muscles are seen converging toward this much modified outer ear. The exact insertion of these, as well as the rest of the modified ear muscles of the two species, is shown in figures 2 and 3. The three smaller of the four extrinsic ear muscles visible in figure 3 belong to postauriculo-occipital muscle group (mm. auriculares posteriores), while the larger one (m. auricularis superior) represents the preauricular muscle group. Extensive remodeling has taken place within the postauriculo-occipital musculature of the seal, so that the original ground-plan of this muscle group is no longer as clearly indicated as in the sea-lion and the terrestrial carnivores. Evidently the cervico-auricular muscle sheet in the seal became interrupted in its course of development. The proximal section, which retains a large portion in direct connection with its matrix (the deep section of the nuchal platysma), still arises from the middorsal line. It extends downward and forward toward the occiput, where it is secondarily connected by a small tendinous sheet with the posterior end of the frontal musculature. The distal portion of the cervicoauricular sheet has settled down close to the outer ear opening. It is represented by the three small mm. auriculares posteriores above referred to.

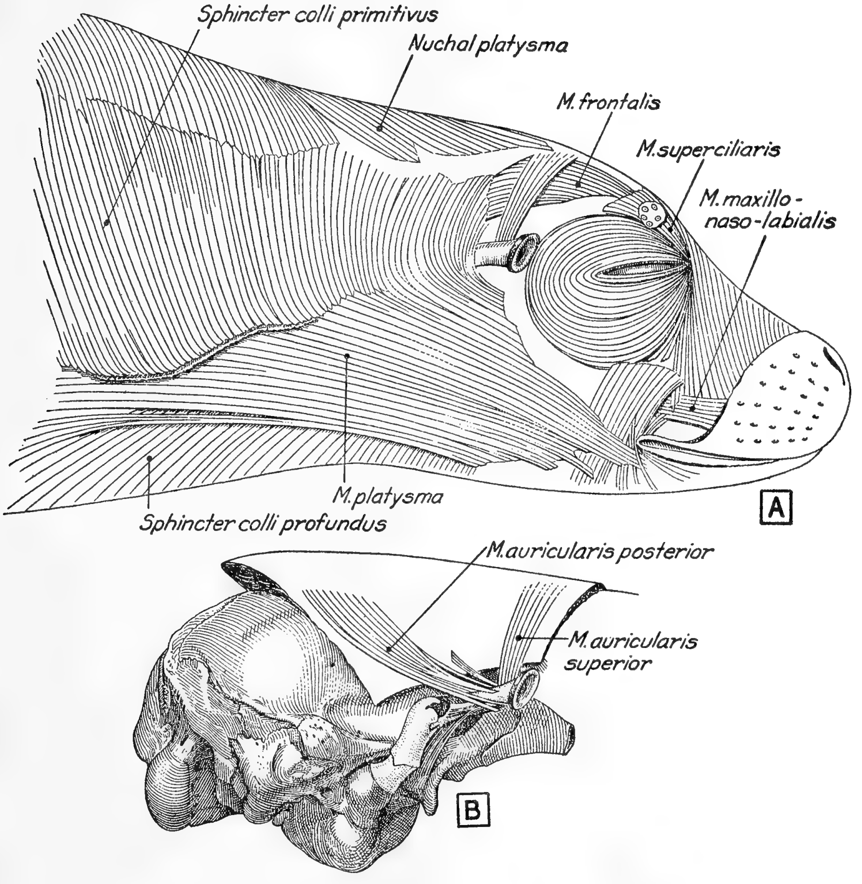


FIG. 3—*Phoca groenlandica.* A, superficial facial musculature; B, posterior part of the skull, showing details of the extracranial parts of the auditory apparatus.

On the occiput the m. occipitalis, as part of the postauriculo-occipital muscle group, has become completely independent. A large part of it is covered, posteriorly by the proximal section of the cervicoauricular muscle sheet and anteriorly by the m. frontalis.

The Sphincter Colli Profundus and its Derivatives

The sphincter colli profundus, largely covered by the platysma layer, forms a continuous transverse stratum which extends forward as far as the mouth, as in the sea-lion and the terrestrial carnivores. The most caudal section, however, has partly deteriorated, having relinquished its connection with the ear, while in the sea-lion and the terrestrial carnivores it is attached as a definite muscle band (pars auris) to the outer ear.

Derivatives of the Pars Preauricularis

Brief reference has already been made to the m. auricularis superior and to the m. frontalis. The latter is represented by a well-developed muscle which arises under cover of the m. orbicularis oculi from a strong ligament on the supraorbital margin. Although fully independent, it still indicates close topographic relationship with the m. nasolabialis and the m. superciliaris, which is situated between the m. nasolabialis and the supraorbital section of the m. orbicularis oculi. The supraorbital muscle tract of the carnivore ground-plan referred to in the section on the sea-lion is thus still readily recognized in the plan of the facial musculature of the seal. The m. orbicularis oculi of the seal lacks those diverging bundles at the lateral angle of the eye, characteristic of the carnivore ground-plan. In the seal the bundles of the m. orbicularis oculi occur as an uninterrupted and very powerful sphincter around the lids. While in the sea-lion the m. auriculolabialis (zygomaticus) of the carnivore ground-plan is represented by a rather feeble vestigial muscle, which has retained its primary connection with the infraorbital section of the m. orbicularis oculi, this muscle has completely disappeared in the seal.

Derivatives of the Pars Oris

In figure 2B the m. orbicularis oculi and m. nasolabialis are partially left in place to show their topographic relationships to the derivatives of the pars oris. Through partial removal of the latter, portions of the m. buccinatorius and m. maxillonasolabialis are exposed. The m. buccinatorius exhibits an arrangement similar to that in the sea-lion. It consists of a superficial circular and a deep longitudinal portion which inserts into the upper and lower lips under cover of the former. The deep part is closely adherent to the mucous membrane of the cheek.

The m. maxillonasolabialis consists of a labial and a nasal part, which are separated by the m. nasolabialis. They are, however, not as well defined as in the sea-lion. The pars labialis, lying superficial to the main layer of the m. nasolabialis, is overlapped by the loose muscle fibers intermediate between the m. orbicularis oculi and the m. nasolabialis. The pars nasalis of the m. maxillonasolabialis is further split into three smaller portions.

The m. mentalis (fig. 2B) shows an arrangement similar to that in the sea-lion. Some of the bundles of the pars oris sphincter colli profundi have kept their genetic relationship with the m. mentalis, while the buccinator bundles have retreated farther back on the alveolar border of the mandible.

The m. nasalis arises from the maxilla in the neighborhood of the nasal opening. From there its bundles radiate through the tough mystacial part. The arrangement of this muscle and its function are largely the same as in the sea-lion.

CETACEA

The whales are unique in their modifications of the facial musculature, parts of which are reduced to mere vestiges or have disappeared altogether, while others are remodeled and curiously specialized. Nevertheless they indicate the plan of facial musculature of the ancestral stock before extreme adaptation to pelagic life had taken place.

The facial muscles auxilliary to the blow-hole apparatus, to the eyelids, and to the ear, will be discussed more in detail in succeeding chapters, while this section includes merely a brief description of the plan of the superficial facial musculature in the cetacean types dissected.

Tursiops truncatus

The general arrangement of the superficial facial musculature is indicated in figure 4A. In the area transitional from trunk to head is found a sphincter colli primitivus layer, which continues caudalward to join the panniculus carnosus, while its ventral part continues rostralward with the muscle layer representing the sphincter colli profundus. Curiously enough, however, the porpoise has lost all trace of a platysma colli et faciei except for the deep layer of the nuchal portion. The latter is not clearly separable from the dorsal section of the sphincter colli primitivus and anteriorly, immediately adjacent to it, is a small vestige of the extrinsic postauricular musculature. Its bundles converge toward the region where, in figure 4A, a square piece of skin has been left to mark the minute lumen of the outer ear.

The sphincter colli profundus, in direct continuation with the ventral section of the sphincter colli primitivus, extends as a vestigial, transverse layer forward as far as the base of the rostrum, from which has become separated a vestigial pars oris. The derivatives of the sphincter colli profundus have partially deteriorated. Other parts of it, however, are very well developed and highly specialized.

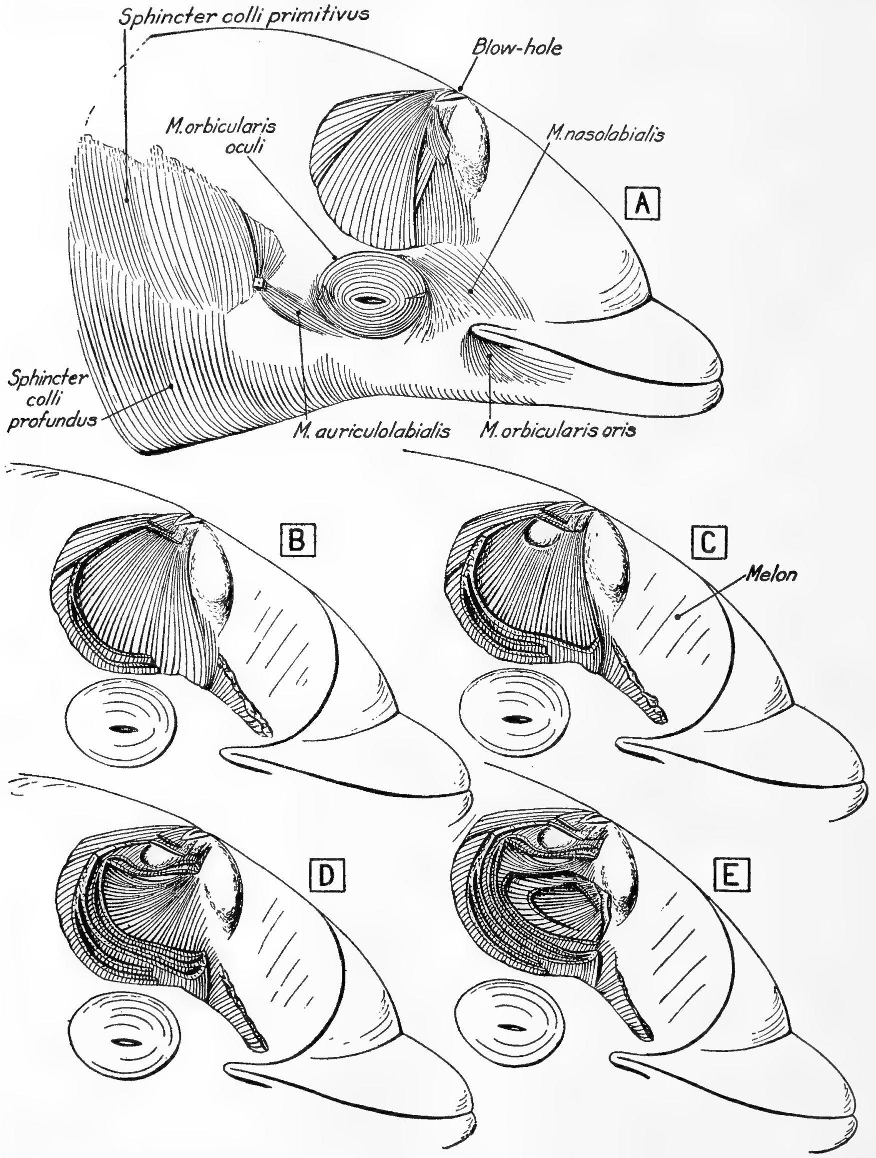


FIG. 4—Facial musculature of *Tursiops truncatus*, showing superficial arrangement and successively deeper layers of the blow-hole musculature.

A muscle corresponding to the m. auriculolabialis (zygomaticus) passes from the preauricular region rostralward to fuse with the lower margin of the m. orbicularis oculi, while its distal continuation has degenerated. Strikingly well developed is the m. orbicularis oculi, which forms a powerful sphincter around the eye, its bundles being closely applied to the freely movable eyelids. One would hardly imagine that behind this narrow eyelid occurs a large eyeball.

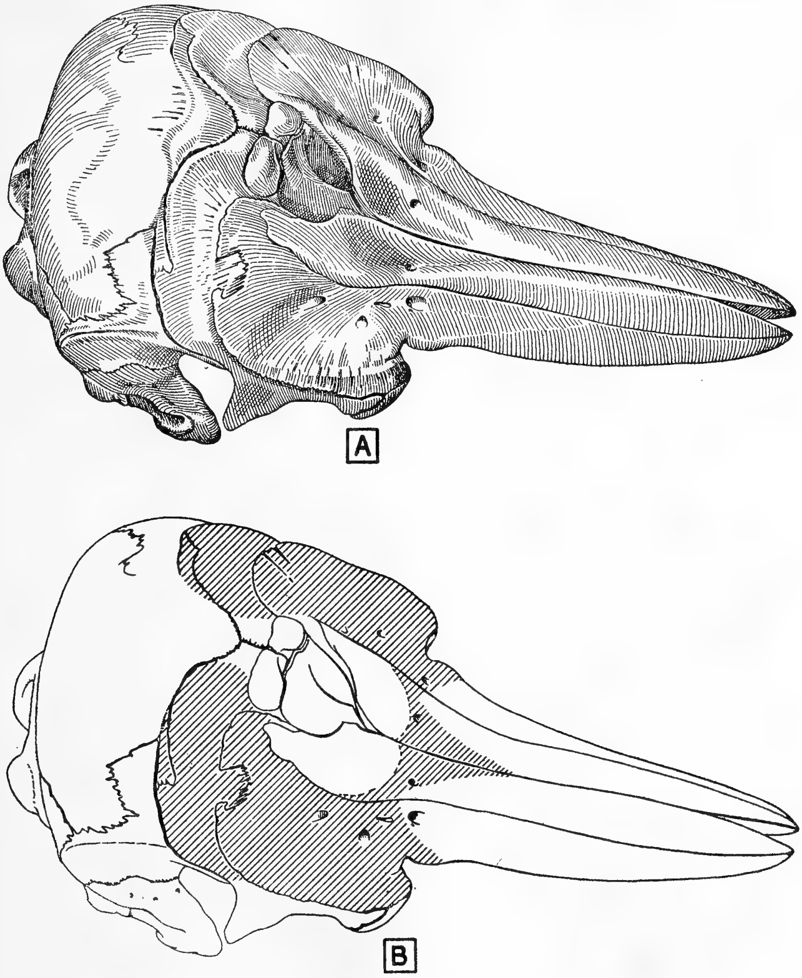


Fig. 5—Skull of *Tursiops truncatus*. A, general view; B, indicating area of attachment of the facial musculature.

Anterior to the m. orbicularis oculi (and still in primitive connection with it) there is a vestigal m. nasolabialis.

There is little left of the m. orbicularis oris (pars oris of the sphincter colli profundus). Its bundles, representing the lower portion, are located close to the angle of the mouth, radiating downward and forward. The usual upper part was unrepresented, as was the m. buccinatorius.

The upper maxillary part as well as the end of the lower mandibular part of the rostrum were found to lack muscle fibers.

The elongated maxillary and premaxillary bones contribute to a rostrum strengthened and bolstered with a layer of extremely tough, subcutaneous tissue over which the skin is smoothly stretched. Located between the blow-hole and the rostrum proper is a rounded protuberance. The latter, unlike the rostral projection, is elastic. This, commercially termed the melon and formed of relatively soft fat, is kept under tension by layers of muscle contributed by modified parts of the pars labialis of the m. maxillonasolabialis.

By far the most conspicuous part of the facial musculature is that connected with the blow-hole mechanism. In figure 4A only the most superficial of these muscles are shown converging upward toward the blow-hole, which, during phylogeny, has shifted from the anterior end of the snout to the top of the head. Externally this orifice appears, when closed, as a transverse, crescentic slit, and when open it is seen that the two nostrils, distinct proximally, have fused distally to form a single opening, characteristic of the Odontoceti.

In figure 4E it is shown that the musculature controlling the blow-hole consists of as many as eight layers arranged in a complex fashion. Figure 5B gives a clear conception of the relatively vast extent of the origin of the blow-hole musculature from the frontal, the maxillary and the premaxillary bones.

The Melon

There is another structure on the head of the Odontoceti which attracts attention. Anterior to the blow-hole, there is an accumulation of fatty tissue commonly called the melon. Figure 4A shows this structure intact, covered with the skin. Strong muscle bundles with insertion into the skin above form a massive muscle wall around this fatty structure. At origin from the upper surface of the maxillary bone and the adjacent lateral border of the premaxilla this musculature is posteriorly continuous with the blow-hole musculature, while anteriorly it extends, but in reduced amount, into the marginal part of the rostrum almost as far as the termination of the latter. The great extent of this whole musculature is indicated in the figures. Innervation by the n. facialis proves that they belong to the facial muscle group. They must represent a singly developed and highly specialized m. maxillonasolabialis.

This bulky musculature is penetrated by several large sensory nerve branches of the n. infraorbitalis trigemini with distribution to the blow-hole region, to the melon and the rostrum. In figure 6 these nerves are shown in their relationship to the skull, as they emerge from several separate foramina of the latter. Accompanying the telescoping of the maxillary and premaxillary bones over the ossa frontalia, their place of emergence has shifted backward. This is most conspicuous in the posterior branches, as indicated in the figure.

Some authors have ascribed to the melon a possible function as a kind of shock absorber. I believe, however, that it has a far more important function. Judging by its position, its construction and its large sensory nerve supply, I suspect that it might enable the animal to appreciate changes in water pressure. It must be remembered that the sinus hairs in the region of the snout which play such an important role in the pinnipeds, the next best swimmers among marine mammals, have disappeared in the porpoise as well as other whales. Only traces of these sinus hairs are found as rudimentary structures in fetal stages. They may persist almost until the time of birth as my full-term porpoise fetus shows.

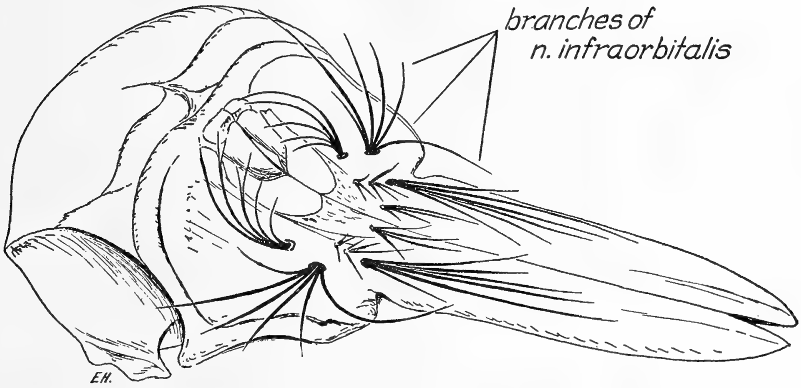


FIG. 6—Skull of *Tursiops truncatus,* indicating distribution of the dorsal sensory branches of the trigeminal nerves.

These important structures could hardly have disappeared unless another mechanism had taken over their vital function. This new mechanism I assume to be located in the melon. Kept under tension by the surrounding muscles and elastic tissue, the melon yields to external pressure. This could easily be demonstrated in the live porpoise. Any change in water pressure when the animal accelerates, when it dives to greater depths, or approaches unyielding objects, will first exert its effect on the head. Even the slightest change in water pressure may thus be appreciated by the animal, with the aid of the sensory nerves which richly supply the melon.

The whalebone whales (Mysticeti) have no melon nor any similar structure. Through the investigations of Japha (Zool. Jahrb., Abth. Anat., 1910), Max Weber and others it has been shown, however, that members of this group have as many as 130 peculiarly specialized sinus hairs in the snout region. These represent modified mystacial and mental vibrissæ. While the bristles of these sinus hairs are vestigial, their hair sheaths persist, and the blood sinuses therein have reached further extension and elaboration. According to Japha, every one of these peculiarly modified sinus hairs is supplied with several hundred myelinated nerve fibers from the infraorbital and mental nerves. These nerve fibers connect with numerous tactile Pacinian corpuscles, which are lodged within the hair sheath and in its immediate vicinity. The occurrence of tactile corpuscles in connection with hairs is unique and confined to whales.

The extraordinarily rich, sensory supply of the modified mystacial and mental vibrissæ in connection with the numerous specialized nerve endings (tactile corpuscles) would, it seems, make the vibrissæ apparatus of the snout of the whalebone whales a most efficient mechanism for the appreciation of slight changes in water pressure. This mechanism could hardly have developed alone in connection with food pursuit, as Japha suggested, but most probably serves the purpose of a hydrostatic organ, taking over the supposed function of the melon in the Odontoceti. Naturally, such a delicate sensory apparatus at the same time might serve as a valuable aid in a search for food.

Thus while the toothed whales, with the exception of *Platanista,* are probably guided chiefly by eye sight in their pursuit of food, the whalebone whales presumably rely mainly on their oral sensory apparatus. It is thus obvious that both the toothed whales and the whalebone whales in their pelagic life are dependent on a highly efficient hydrostatic organ.

The Blow-Hole Mechanism of Tursiops

It is apparent that the external orifice of the blow-hole is naturally kept closed by tension of the surrounding tissue, for it remains thus after death. The external orifice is transversely crescentric, with concave aspect directed forward. The anterior margin is a soft, valve-like structure which presses against the more rigid posterior margin. A fine corrugation on the mucous membrane enables the borders to fit more closely together.

I have endeavored to illustrate in semidiagrammatic fashion (fig. 7) the probable manner in which the muscles operate in maintaining the closed position of the blow-hole. Most superficially there is a thin, half tendinous, half muscular layer with inferior origin from the maxillary and frontal bones, and with superior attachment partly to the nasal bone and partly into the blubber both behind and in front of the blow-hole. When this semitendinous structure contracts, it presses upon the subjacent muscle layers and acts like a strong fascia which holds a group of muscles together, thus increasing their efficiency through joint action. Beneath this stratum there are the different layers, shown in figure 4; in figure 7 they are only suggested.

When the fibers of the muscle layer, arising from the maxillary bone over the orbit and passing straight upward to be inserted about the angle of the orifice, simultaneously contract on both sides they exert a pull on the angles of the opening and effect more complete closure. This could be demonstrated by pulling on the muscles of dissected fresh specimens. These more superficial muscle layers (fig. 7B) are assisted by the deeper layers sketchily represented (fig. 7C), which take origin from the frontal bone and the posterior part of the maxilla. They pass from behind around the blow-hole to be inserted anterior thereto into a tough mass of connective tissue. Histological examination shows that this is made up of an extremely tough, condensed felting of connective tissue fibers. When this elastic cushion is pulled backward by the muscles comprising the layers shown in figure 4, the anterior, valve-like lip of the blow-hole is automatically pushed upward and backward toward the posterior lip, as indicated by the three arrows in figure 7C, thus effecting secure closure.

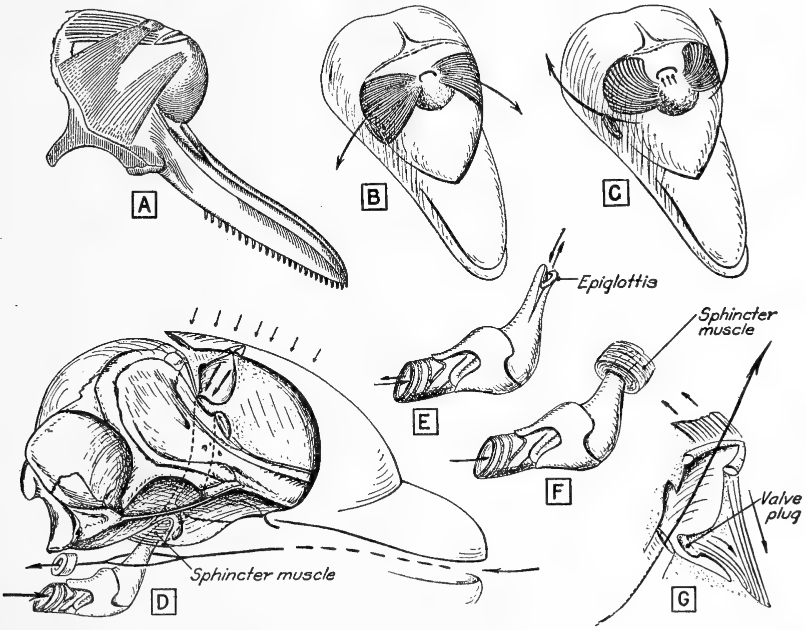


FIG. 7—*Tursiops truncatus.* A, B, C, schematic presentation illustrating muscular action in closure of the blow-hole; D, illustrating relationship of the pharynx to the nasal passages, between respirations; E, epiglottis open; F, epiglottis closed and clasped by sphincter muscle of the choanæ; G, schema of the open spiracle.

In addition, a second mechanism facilitates this action. The principle is demonstrated in figure 7G, where the unpaired blow-hole connects with the paired, bony, nasal passages. Here, on either side, there is a plug which fits exactly into the upper opening of the two bony narial passages. Examination of the living porpoise revealed that while the external blow-hole is closed, air appears to be retained within the distal nasal passage and the diverticula connected with the latter. This air is forcibly retained by muscle action. The musculature concerned with the closing of the blow-hole orifice evidently compresses the air-filled lumen and forces the air against the plugs as suggested by the arrows in figure 7D. The plugs thus tightly close the entrance into the bony nasal passages.

But this is not all. A third mechanism is provided to bring about an ideal closure of the air passages and to enable the animal to retain in the lungs a large amount of inspired air. This is through the complete closure of the larynx.

In the larynx of the porpoise (as well as of other whales) the epiglottis and the arytenoid cartilages are elongated, forming a beak-like projection (fig. 7E). The epiglottis anteriorly has a groove into which the folded arytenoid cartilages fit. This peculiar structure projects anteriorly into the choanæ, the lower end of the paired bony narial passages. There it is held in place by a very powerful sphincter muscle which is part of the palatopharyngeal musculature. In this way a direct communication is established between the narial passage and the lungs. The respiratory tract is thus fully segregated from the anterior part of the digestive tract. In the dead animal the larynx, after complete relaxation of the surrounding sphincter muscle, can be pulled out of this position, as suggested in the figure.

In order to open the air passages for breathing, the triple closure above described must be released. First the musculature responsible for closing the blow-hole orifice and for compressing the lumen must relax. This could actually be observed in the live porpoise. Part of the air contained in the blow-hole may thus escape. The plugs in the entrances into the bony nasal passages are then elevated by the strong retractor muscles. At the same time the dilator musculature of the blow-hole orifice pulls the anterior, valve-like margin forward and down, while the more rigid posterior lip is kept in tension by the contraction of the musculature which inserts from behind into the posterior margin of the orifice. The blow-hole is thus widely opened. Simultaneously the palatopharyngeal sphincter muscle relaxes, and through the contraction of the strongly developed mm. crico-arytenoideus, thyreo-arytenoideus and hypo-epiglotticus, the tube formed by the elongated epiglottis and the arytenoid cartilages is opened. The entire air passage from the lungs through the short, rather rigid trachea and the larynx into the paired bony nasal passages, and from these through the blow-hole, is now free. Through forceful contraction of the chest muscles, as could be observed in the live animal, and probably through additional action of the diaphragma, the air is forced out and inspiration immediately follows. Then the triple mechanism, described above, again closes tightly until the next expiration occurs.

This analysis leads me to discuss some fundamental points concerning the gross structure and the topography of the lungs. In a few adult porpoises which were captured and killed at the porpoise fishery at Cape Hatteras, and in a stranded young porpoise, pulmonary conditions could be examined. These were found to be the same in my full-term porpoise fetus and in fetuses of *Globiocephala*. Upon exposing the thoracic cavity it was seen that the diaphragma, separating the abdominal from the pleural cavities, is not in a transverse position as in terrestrial mammals, but slants markedly backward. The pleural cavities thus extend backward over a large part of the trunk. This is most significant in connection with the functioning of the respiratory organs.

The lungs show peculiar characteristics fundamentally alike on both sides. At first glance there seems to be no lobation, and such statements are found in the literature. A more careful examination, however, reveals vestiges of lobes in the anterior part of the lungs. From observations upon the living animal, correlated with later dissections, it is evident that the inflated lungs expand forward as far as the transitional zone between the head and trunk, as well as far backward.

In the live porpoise it was found that in the intervals between the acts of respiration, air was retained in the blow-hole as mentioned above, presumably in order to press the plugs tightly into the entrance of the bony narial passages. It could be observed that sometimes, when part of the air threatened to escape, the porpoise made all effort to retain it, and the contraction of the involved blow-hole muscle was then clearly indicated. It may be assumed that while the animal is under water the equalized water pressure against the lips of the closed blow-hole would assist the muscle action.

By pressing against the lateral walls of the air-filled blow-hole, I succeeded in causing the air to escape against the will of the animal. This action, I assume, forced the plugs from the entrances to the bony nasal passages and compelled expiration. By repeating this experiment it was possible to force the porpoise to blow as many as seven successive times during the interval in which it normally would have breathed but once. The animal thereby became much excited. This experiment appears to indicate that the air forcibly retained within the blow-hole is necessary for tight closure of the air passages between respirations. After death and in the unborn young the blow-hole and its diverticula are found collapsed, their walls lying closely adpressed.

Monodon monoceros

Though similar to the porpoise in its general arrangement of the facial musculature, the narwhal exhibits differences which necessitate a separate description. The investigation of this animal was much more difficult in several respects than was that of the porpoise. After having intensively studied facial musculature for a period of many years, I met with the greatest difficulty when I began the investigation of a large, full-term narwhal fetus, which differed radically from any one of the manifold mammalian types I had previously investigated.

Even skinning the head of this animal was a problem in itself, since the corium and subcutaneous tissue form such a thick, tough layer of blubber, which had to be removed bit by bit. Then I found that in some regions of the head the subcutaneous tissue and the musculature were penetrated by oil-filled sinuses of variable size and extent (fig. 8A). Among these was a huge cavern involving several muscles. The homology of these muscles was somewhat obscured by invaginations from the main oil sinus and by additional smaller sinuses which extended throughout the intermuscular tissue of this region. When such caverns were encountered during dissection, the oil exuded so freely as to swamp the field of dissection and cause trouble. In addition there was a large number of peculiar venous spaces which made the subcutaneous tissue and the facial musculature in some regions, as in front of the ear and about the eye (fig. 8A), appear like cavernous tissue. Moreover there are in the region of the snout heavy masses of muscle bundles which radiate through the thick, tough, subcutaneous tissue to be inserted into the skin. It is obvious that these conditions necessitated a modification of the usual dissecting methods. In fact, I had here to cut out entire blocks consisting of skin, subcutaneous tissue and musculature. Only by carefully planning the dissection as though it were for an operation could one expect to be successful in a study like this. But even if one overcome all these technical difficulties and succeed in dissecting the facial musculature, one experiences great difficulty in interpreting the relationship of the various elements. A critical review of the accounts given by the authors who have attempted the study of the whale's facial musculature clearly evidences this fact. Using the innervation as a guide and taking into consideration the fundamental changes which have taken place in the skull and in the soft parts connected with the blow-hole, I could come to more definite conclusions, where previous investigators had merely speculated.

There was a considerable degree of asymmetry encountered in the musculature of the two sides of the head. Upon the right the sphincter colli primitivus was similarly arranged as in *Tursiops*. It

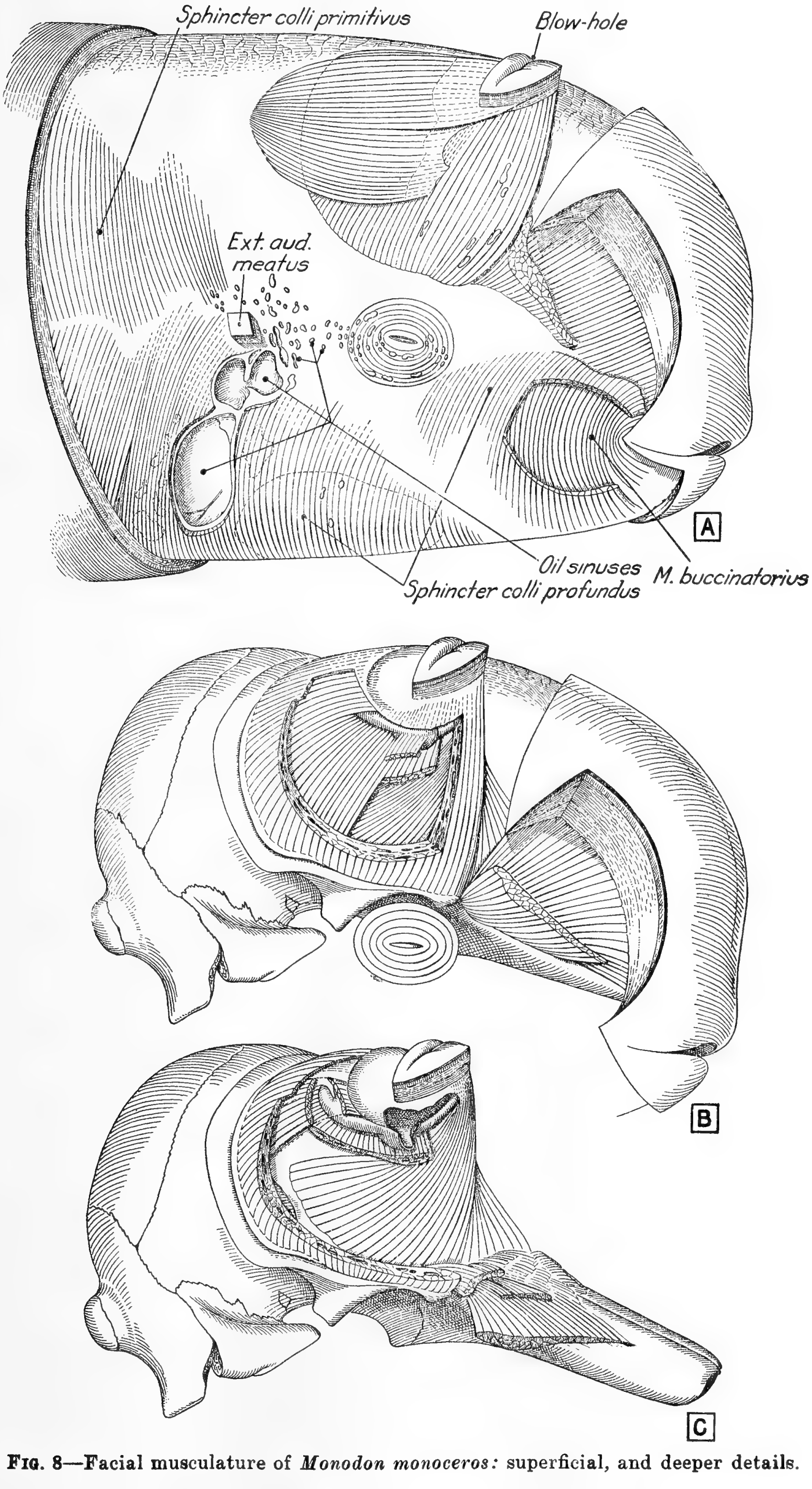


Fig. 8—Facial musculature of *Monodon monoceros:* superficial, and deeper details.

continued caudalward with the panniculus carnosus, while its dorsal section was continuous with those muscle bundles which may be interpreted as vestiges of the deep layer of the nuchal platysma and postauricular musculature. The ventral section of the sphincter colli primitivus was broadly continuous with the sphincter colli profundus, as in the porpoise. There was likewise no indication of the m. platysma colli et faciei. It is significant that several slips, in part reduced to tendinous structures (as indicated by interrupted lines in the figures) extended for a short distance below the ear oralward, here overlapping the pars auris of the sphincter colli profundus. One may presume that these vestigial slips in earlier phylogenetic stages of the whales formed a continuous longitudinal muscle layer (m. platysma colli et faciei) which extended, superficially to the sphincter colli profundus, oralward as far as the mouth. This muscle layer has become reduced, thus leaving the sphincter colli profundus exposed as in the porpoise.

Although the m. occipitalis is lost, as in the porpoise, the rest of the postauriculo-occipital muscle group was more elaborate on the left side than the right. It was found still in close, primitive relation with the vestigial nuchal platysma and inserted with several slips, representing the mm. auriculares posteriores, into the greatly reduced ear tube.

The sphincter colli profundus occurred in continuation with the sphincter colli primitivus, and was still more extensive than in the porpoise. The pars auris was largely reduced to a tendinous plate, which in contrast to conditions found in the porpoise has retained its attachment to the vestigial outer ear. The pars auris was directly continuous with the pars preauricularis and with the ventral section of the pars palpebralis. The dorsal section of the latter and the pars oris formed a single sheet, having become separated from the rest of the sphincter colli profundus layer. All these muscle divisions were, however, readily recognized as belonging to an originally continuous layer, small as we still find the sphincter colli profundus in the seal and the sea-lion. The pars oris, in contrast to conditions found in the porpoise, was fairly well developed. There was also a deeper layer, comparable to a very simply constructed m. buccinatorius, lining the buccal wall. The vestibulum oris was reduced to a small diverticulum starting inside the lower lip and extending for a very short distance lateral to the angle of the mouth, while the upper lip was directly continuous with the hard palate. Both upper and lower lips are rigid structures. The mouth of the narwhal is toothless, except for the one modified incisor.

The preauricular section of the m. auriculolabialis was reduced to a tendinous platelet, while in its forward continuation it broadened into a well-defined muscular band which passed below the m. orbicularis oculi to dip under the pars palpebralis of the sphincter colli profundus. There it continued for a short distance without, however, reaching the angle of the mouth.

The m. orbicularis oculi was well developed and formed, as in the porpoise, a closed sphincter muscle around the eye. Curious modifications of the skin over the eyelids make closure of the lids possible, as later discussed. As in the porpoise, the blow-hole musculature has extensive origin from the maxillary, premaxillary and frontal bones. It is even more complex in the narwhal than in the porpoise, in conformity with the more complicated blow-hole of the former. According to the author's interpretation, the muscle bundles concerned with the snout represent the modified pars labialis of the m. maxillonasolabialis while that of the various divisions of the blow-hole musculature are derived from the pars nasalis of the m. maxillonasolabialis.

The Blow-Hole Mechanism of Monodon

The blow-hole apparatus of the narwhal is even more specialized in some respects than that of the porpoise. In figure 8 is given an idea of the general arrangement of the musculature concerned with the blow-hole and of the whole mechanism in relation to the skull. The construction of the apparatus is largely the same as in the porpoise. We may hence assume that the function is similar. I shall therefore refrain from a detailed discussion, but rather consider some points which I have only touched upon before.

Various authors have attempted to homologize the blow-hole structures with conditions in other mammalian types. These have generally resulted in a rough comparison only, without any sound foundation. It is thus obvious that Murie (Jour. Anat. Physiol., vol. 5, 1871; Trans. Zool. Soc. London, vol. 8, 1874), in his descriptions of the blow-hole musculature of various representatives of the toothed whales, went too far in homologizing every one of these layers with one of the facial muscles of man, including the m. occipitofrontalis, the various muscles of the cheek region and of the nose.

I have emphasized the fact that the muscle-nerves serve as guides in establishing muscle homologies. If the blow-hole muscles of the whale really corresponded to the m. occipito-frontalis and the various muscles of the cheek region and nose of man, we should find those muscles innervated by twigs of the postauricular branches, as well as by supra- and infraorbital twigs of the preauricular branches of the n. facialis. The fact, however, is that the n. facialis (fig. 9), after having given off a few minor branches to the rudimentary ear muscles, the sphincter colli profundus, orbicularis oculi, et cetera, curves around the preorbital apophysis of the maxillary bone just anterior to the orbit where it divides into a number of branches, some of which curve upward and backward, splitting again into many twigs, which supply the main bulk of the blow-hole musculature. Two of the terminal branches curve forward once more and then medially to supply additional portions of the blow-hole musculature. The most anterior branches, dividing into several smaller twigs, supply the massive musculature which inserts into the base of the rostrum, including those muscle bundles which penetrate and surround the melon.

The peculiar condition of these nerves reveals a remarkable story, giving the clue to the analysis of the phylogenetic differentiation of the blow-hole musculature. The nerve supply indicates that these muscles have differentiated from one source. The matrix must originally have been located on the anterior part of the head. While the maxilla telescoped over the frontal bone, this matrix muscle arising from the maxillary bone must have been shifted backward carrying the nerve supply with it. The corresponding terminal branches were thus drawn out and curved around the preorbital apophysis of the maxilla. This is the explanation for the peculiar first curve of the facial branches referred to above.

Following the differentiation of the blow-hole musculature into layers, the nerve branches split into numerous subdivisions. These branches are of considerable size, corresponding to the powerful development of this musculature which has expanded over a large part of the maxilla and from there to the adjacent border of the frontal bones, over which the maxilla had spread. With the gradual elaboration and perfection of the complex blow-hole mechanism, part of this musculature has also migrated forward and medially, settling down on the surface of the premaxilla and thus forming a muscle which could directly act on the valves which plug the entrance into the bony narial passages. This muscular portion has become the retractor muscle of these valves. The latter very likely represent transformed parts of conchæ deprived of bony and cartilaginous support. A vestige of the cartilaginous skeleton of the nose is represented by a bit of cartilage in the nasal septum close to the entrance to the paired narial passages. The migration, forward and medially of this retractor accounts for the second curve of the terminal facial branches, which innervate the retractor muscle of the plugs.

Correlating the nerve supply, the origin and insertion of the musculature and the changes which have taken place in the skull and the soft parts of the nose, I came to the conclusion that the entire muscle mass which arises from the maxillary bones, from adjacent parts of the frontalia and premaxillæ, represent the singly developed m. maxillonasolabialis. The two portions of this muscle, pars labialis and pars nasalis, have retained their primitive connection at origin near the preorbital apophysis of the maxillary. The pars nasalis has become a powerful and highly specialized part of the complex blow-hole musculature, while the pars labialis, likewise unusually developed, forms the musculature of the rostral part of the head, including the portions associated with the melon.

I am unable to decide whether the thin layer of the blow-hole musculature that is most superficial in the narwhal came from the same matrix as the rest of the blow-hole muscles, since I did not succeed in establishing its nerve supply. In the porpoise, however, I found the whole bulk of the blow-hole musculature innervated by the corresponding terminal branches of the n. facialis. There was the same characteristic double turn in their course, as described and pictured in the narwhal.

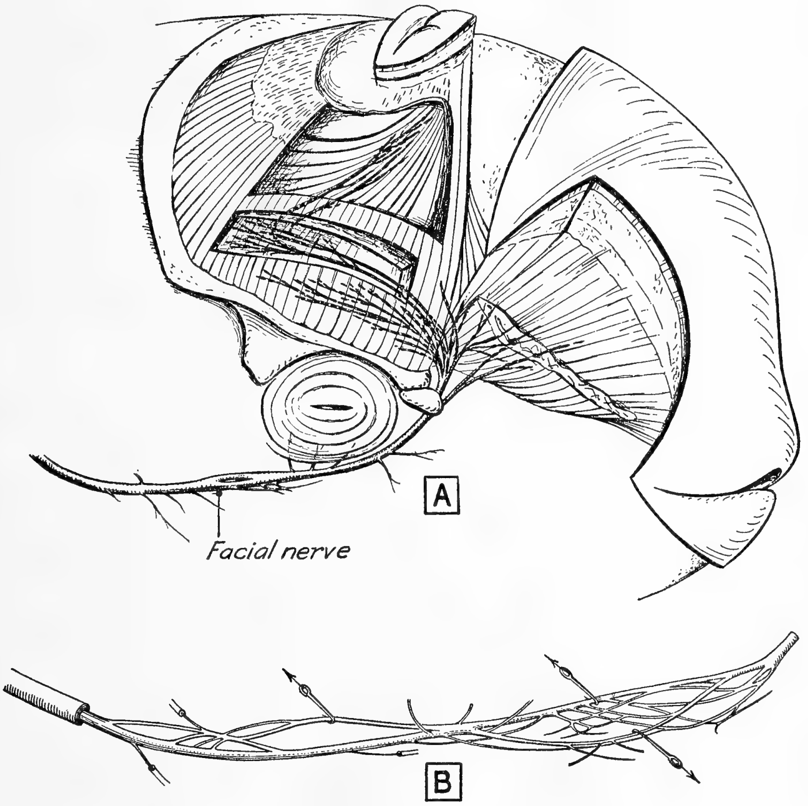


Fig. 9—*Monodon monoceros.* A, distribution of the facial nerve; B, trunk of the facial nerve with fibrous sheath removed.

Not only in this detail but in all respects is the cetacean facial nerve noteworthy. Unlike the situation in other mammalian types this nerve is a relatively simple device in the whale. Emerging from the facial foramen in the mastoid region, the large stem of the facialis takes an almost horizontal course rostralward, giving off only minor branches, until it finally divides into the large terminal branches for the blow-hole musculature and the musculature of the rostrum, as described above. The usual plexus formation, so characteristic of the other mammals, is absent but this relatively great simplicity of the facial nerve is more apparent than real. If the heavy sheath around the facialis stem be removed and examined more closely, we become aware that there is a complex network present (fig. 9B), suggesting conditions found in the rest of the mammals.

According to my explanation these peculiar conditions are in close causal connection with the transformations which have taken place in the skull and the soft parts. Through the telescoping of the maxilla over the frontal bones and the consequent shifting backward of the maxillonasolabialis muscle mass together with its innervation, the whole n. facialis must have experienced tension. The network formed by the facial branches was thereby stretched, so that these came to lay very close together and consequently were enclosed in a heavy connective tissue sheath, which can only with difficulty be separated from the surrounding tissue adherent.

I have mentioned that in certain respects the blow-hole mechanism of the narwhal is more highly differentiated than that of the porpoise. This applies particularly to the construction of the blow-hole cavity (spiracular cavity) and its diverticula, which are more numerous and of greater extent. Three pairs of fairly large nasal sacs communicate with the blow-hole cavity and there is an additional pair of smaller, lateral recesses off the main cavity. In figure 10A incisions have been made in the borders of the blow-hole and these have been pulled apart to allow a view within. The sacs may be termed as follows: An anterior, premaxillary pair resting upon the premaxillæ, their extent indicated by dotted lines in figure 10B; a posterior, nasofrontal pair, resting upon the nasal and frontal bones; an anterolateral pair which posteriorly communicate with the nasofrontal sacs, while anteriorly they almost meet in the midline. [Some of Dr. Huber's sketches would indicate that there is, and others that there is not, anterior communication with the main blow-hole—A. B. H.] The lateral recesses have a cup-like form lateral to the blow-hole.

In the next figure (10B) a large part of the anterior blow-hole wall has been removed to show the valves. These are partially pulled from the bony narial nassage. The retractor muscles of the plugs are now fully exposed, and, through an artificial opening one may see into the anterior, premaxillary sacs. By further resection of parts and removal of the plug on one side, the slipper-shaped interior is fully exposed and the communication of these sacs and the anterolateral pair, with the posterior, nasofrontal sacs, become visible.

After retraction of the plugs, the nasofrontal sacs are seen to communicate directly with the bony narial passages. Figure 10C indicates the plan of the narial passages and diverticula when inflated.

I have been much puzzled by the possible significance of these different structures and about the way in which the whole apparatus might function. The construction of the main blow-hole cavity and the anterior and posterior nasal sacs is essentially the same in both narwhal and porpoise, but an attempt should be made to explain the significance of the third pair of anterolateral sinuses. The following explanation seems, to my mind, quite reasonable. I assume that the narwhal, in a manner similar to the porpoise, takes in a maximal amount of air on inspiration. From the general arrangement of the structures we may assume that the air contained in the comparatively wider main cavity of the narwhal blow-hole and the large anterior, premaxillary sacs may, from above and from in front, press the plugs firmly into the entrance of the bony narial passages; while, on the other hand, through the contraction of special muscles connected with the comparatively large posterior, nasofrontal sacs and the adjacent section of the anterolateral sinuses, the air from the posterior nasofrontal sinuses can be evacuated into the anterolateral sinuses where it may be stored.

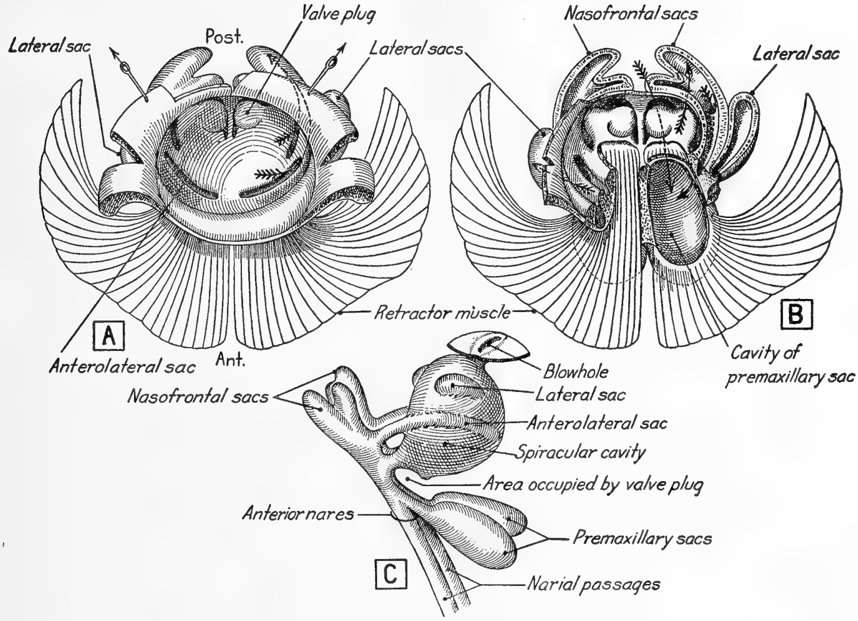


FIG. 10—Interior details of the blow-hole apparatus of *Monodon*. A, with margins reflected; B, dissected details; C, reconstruction of spiracle and associated diverticula.

When the whale comes to the surface to blow, it is obliged to open the valves which plugged the entrance into the bony narial passages. These valves will ease off a bit the instant the animal relaxes the musculature around the blow-hole, and interaction of the musculature inserting on the walls of the sinuses allows the withdrawal of the plugs from the narial passages.

The Outer Ear of the Narwhal

The outer ear of the whale has undergone extreme reduction. The pinna probably became reduced very early in cetacean phylogeny and has finally disappeared completely, while the ear tube in a modified form must have been functional for a longer period. How such a gradual transformation might have taken place can be judged from the analogous situation in the earless seals (Phocidæ), where the outer ear probably still functions in a manner similar to the case in the remote ancestors of the whales. While in the seals the lumen is of average diameter, in the whale it occurs as a vestigial organ only, reduced to a small tube with a minute opening at the outer surface. This pore is marked in figure 11 as a small dot on the quadrangular piece of skin which is left in place. The auditory tube of the modern whales may be considered as functionally closed. The ear drum has become useless and is no longer capable of transmitting air-borne sounds. Important changes in the construction of the ear mechanism have taken place, however, to enable the whale to detect water-borne vibrations. The ossicles of the middle ear are ankylosed and a huge coiled bulla has developed. It is clear that this sense must now in-

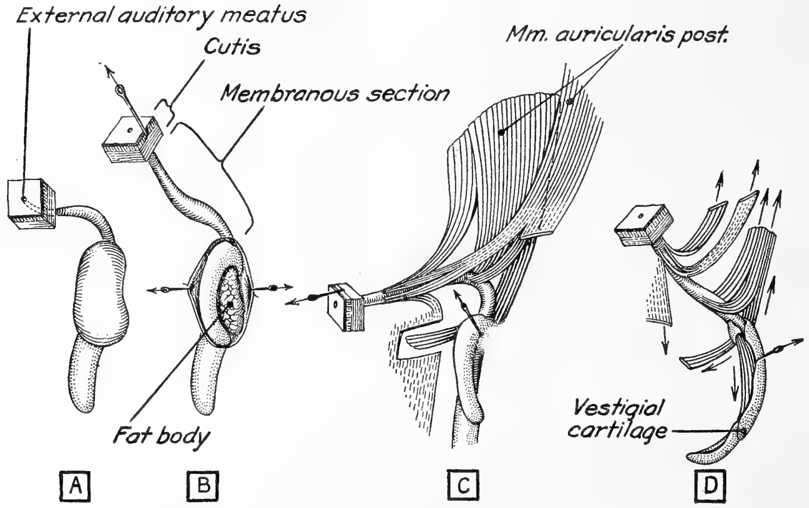


FIG. 11—Details of the extracranial auditory apparatus in *Monodon*.

volve the direct conduction of sound waves through the bones of the head.

In spite of the rudimentary condition of the functionless outer ear of the modern whales, the essential parts, including the whole muscle apparatus and its nerve supply, have been retained. Figures 11A and B show the ear tube without its musculature. It consists of a proximal section supported by cartilage and a distal membranaceous part. In figure 11A the ear tube is shown in natural position. The small bean-shaped structure between the cartilaginous and membranous parts is a tough capsule of connective tissue. This surrounds a part of the cartilage which contains, in a notch, a small fatty body (fig. 11B). The ear musculature is illustrated in figures 11C and D. Even at a time when the membranous part of the ear tube was of larger diameter, this likely was kept collapsed by the pressure of the surrounding tissue and of the water, while the cartilaginous part of the lumen undoubtedly was expanded.

Several small facial muscles insert upon the lumen between the membranous and cartilaginous parts. Tension of these slips can dilate the proximal part of the membranous section. Two more of these muscles insert into the continuation of the latter and three of them are grouped about the most distal part very close to the external orifice. Through joint action of all these slips, the collapsed part of the lumen could be dilated.

The Narwhal Eyelid

If one superficially examines the eye of the narwhal he might think it impossible that the animal could close the eyes, since the horny, superficial layer of the skin can hardly be expected to allow any movement. A more careful examination, however, removes the least doubt of this.

In order to demonstrate the closure mechanism of the eyes, it is necessary that the construction of the narwhal's skin be briefly discussed. Figure 12A shows a sagittal section through the skin taken from the rostral part of the head of a narwhal fetus. The three main parts of the mammalian skin are represented in a modified form, the epidermis, the corium and the subcutaneous tissue. The surface is smooth and hairless, allowing the animal to pass through the water with a minimum of friction.

The epidermis consists of several distinct layers. First there is an exceedingly thin, transparent and somewhat horny cuticula, covering a thicker, black stratum with more than a suggestion of cornification, at least in the preserved animal. Beneath the second is a third layer of tough, grayish, cellular epidermis, darkly pigmented in its deeper portion and easily separable. It presents a surface somewhat similar in appearances to the ragged bark of a tree, and unlike the first two this layer is quite freely flexible.

Well differentiated from the deepest layer of the epidermis is the corium, composed of extremely tough, connective tissue, practically inseparable from the tela subcutanea. The corium and the subcutis together form the structure commonly termed the blubber.

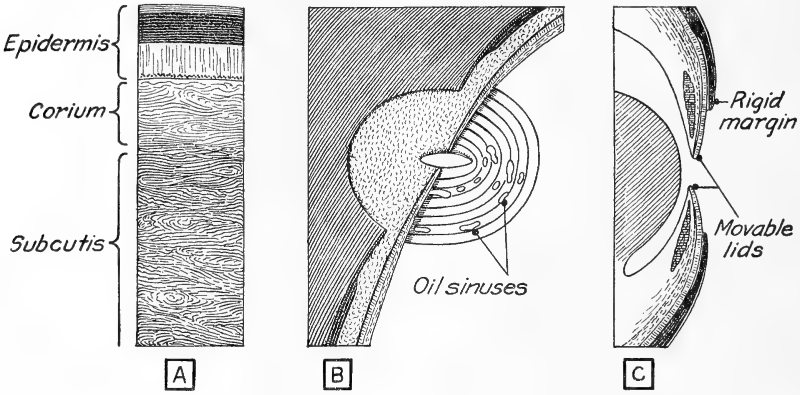


FIG. 12—The skin of *Monodon*. A, cross-section of skin; B, details about the eye; C, cross-section through the eyeball.

About the eyes of the narwhal the skin is remarkably modified. Here if the rigid, superficial layer of the epidermis extended as far as the rim of the lids, the latter would be immovable and it would thus be impossible for the animal to close its eyes. On the contrary, however, the superficial layer, reduced in thickness, stops short of the eye, and its margin at the first glance might be mistaken for the eyelids. Inside this rigid frame the deep, cellular, movable epidermis layer, with its surface slightly cornified and pigmented, continues in a thin sheath as far as the actual eyelids. Beneath this epidermis layer is the blubber, in a considerably thinner layer. The eyelids inside the black, rigid frame are thus entirely movable, and the narwhal is capable of closing its eyes by contraction of the well-developed m. orbicularis oculi.